SEP 30 1921
SEP 30 1921
UNIV. OF MICH.

VOL. XIII, NO. 4 OCTOBER, 1921

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

CONTENTS

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:
THE CONSTITUTION OF MATTER. Sir T. Edward Thorpe 289
THE LABORATORY OF THE LIVING ORGANISM. Dr. M. O. Forster 301
EXPERIMENTAL GEOLOGY. Dr. J. S. Flett 308
SOME PROBLEMS IN EVOLUTION. Professor Edwin S. Goodrich 316
APPLIED GEOGRAPHY. Dr. D. G. Hogarth 322
SCIENTIFIC IDEALISM. Dr. William E. Ritter 328
FIELD CROP YIELDS IN NEW JERSEY FROM 1876 TO 1919. Harry B. Weiss 342
THE PLAY OF A NATION. Professor G. T. W. Patrick 350
EVARISTE GALOIS. Dr. George Sarton 363
MARS AS A LIVING PLANET. G. H. Hamilton 376
THE PROGRESS OF SCIENCE:
Scientific Meetings; The Activities of the Rockefeller Foundation; The Harvard School of Public Health; Scientific Items 380

THE SCIENCE PRESS
PUBLICATION OFFICE: 11 LIBERTY ST., UTICA, N. Y.
EDITORIAL AND BUSINESS OFFICE: GARRISON, N. Y.
Single Number, 50 Cents. Yearly Subscription, $5.00

COPYRIGHT 1921 BY THE SCIENCE PRESS

Entered as second-class matter February 8, 1921, at the Post Office at Utica, N. Y., under the Act of March 3, 1879.

WITHIN THE ATOM

By JOHN MILLS

(Author of "Realities of Modern Science")

A fascinating non-technical exposition of the structure of the atom and the electron theory.

Describes with entire freedom from mathematics the recent discoveries of Langmuir, Bohr, Millikan, Einstein, and others of our foremost modern scientists.

The charm of its lucid style will appeal to the reader untrained in science.

UP-TO-DATE CLEAR INTERESTING

232 Pages Cloth $2.00 Illus. 5x7¼

Send this "ad." with $2.00 to your dealer, or to

D. VAN NOSTRAND CO.

8 Warren Street New York

Third Edition—Now Ready

AMERICAN MEN OF SCIENCE

A BIOGRAPHICAL DIRECTORY

Edited by J. McKeen Cattell and Dean R. Brimhall

The third edition of the Directory contains about 9,600 sketches as compared with 4,000 in the first edition and 5,500 in the second edition. The work should be in the hands of all those who are directly or indirectly interested in scientific work.

(1) Men of science will find it indispensable. It gives not only the names, addresses, scientific records and the like of their fellow workers, but also an invaluable summary of the research work of the country, completed and in progress.

(2) Those interested in science, even though they may not be professionally engaged in research work, will find much of interest and value to them in the book.

(3) Executives in institutions of learning and others brought into relations with scientific men will use the book constantly.

(4) Editors of newspapers and periodicals will find it to be one of the works of reference that they will need most frequently.

(5) Libraries will find the book to be a necessary addition to their reference shelves.

Price, Ten Dollars, Net, Postage Paid

THE SCIENCE PRESS

GARRISON, N. Y. LANCASTER, PA.

THE SCIENTIFIC MONTHLY

OCTOBER, 1921

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE[1]

THE CONSTITUTION OF MATTER

By Sir T. EDWARD THORPE, C.B., F.R.S.

PRESIDENT OF THE ASSOCIATION

THE molecular theory of matter—a theory which in its crudest form has descended to us from the earliest times and which has been elaborated by various speculative thinkers through the intervening ages, hardly rested upon an experimental basis until within the memory of men still living. When Lord Kelvin spoke in 1871, the best-established development of the molecular hypothesis was exhibited in the kinetic theory of gases as worked out by Joule, Clausius, and Clerk-Maxwell. As he then said, no such comprehensive molecular theory had ever been even imagined before the nineteenth century. But, with the eye of faith, he clearly perceived that, definite and complete in its area as it was, it was 'but a well-drawn part of a great chart, in which all physical science will be represented with every property of matter shown in dynamical relation to the whole. The prospect we now have of an early completion of this chart is based on the assumption of atoms. But there can be no permanent satisfaction to the mind in explaining heat, light, elasticity, diffusion, electricity and magnetism, in gases, liquids and solids, and describing precisely the relations of these different states of matter to one another by statistics of great numbers of atoms when the properties of the atom itself are simply assumed. When the theory, of which we have the first instalment in Clausius and Maxwell's work, is complete, we are but brought face to face with a superlatively grand question: What is the inner mechanism of the atom?'

If the properties and affections of matter are dependent upon the inner mechanism of the atom, an atomic theory, to be valid, must comprehend and explain them all. There cannot be one kind of atom for the physicist and another for the chemist. The nature of chemical affinity and of valency, the modes of their action, the difference in characteristics of the chemical elements, even their number, internal con-

[1] Extracts from addresses given at the Edinburgh Meeting.

stitution, periodic position, and possible isotopic rearrangements must be accounted for and explained by it. Fifty years ago chemists, for the most part, rested in the comfortable belief of the existence of atoms in the restricted sense in which Dalton, as a legacy from Newton, had imagined them. Lord Kelvin, unlike the chemists, had never been in the habit of 'evading questions as to the hardness or indivisibility of atoms by virtually assuming them to be infinitely small and infinitely numerous.' Nor, on the other hand, did he realize, with Boscovich, the atom 'as a mystic point endowed with inertia and the attribute of attracting or repelling other such centres.' Science advances not so much by fundamental alterations in its beliefs as by additions to them. Dalton would equally have regarded the atom 'as a piece of matter of measureable dimensions, with shape, motion, and laws of action, intelligible subjects of scientific investigation.'

In spite of the fact that the atomic theory, as formulated by Dalton, has been generally accepted for nearly a century, it is only within the last few years that physicists have arrived at a conception of the structure of the atom sufficiently precise to be of service to chemists in connection with the relation between the properties of elements of different kinds, and in throwing light on the mechanism of chemical combination.

This further investigation of the 'superlatively grand question—the inner mechanism of the atom,'—has profoundly modified the basic conceptions of chemistry. It has led to a great extension of our views concerning the real nature of the chemical elements. The discovery of the electron, the production of helium in the radioactive disintegration of atoms, the recognition of the existence of isotopes, the possibility that all elementary atoms are composed either of helium atoms or of atoms of hydrogen and helium, and that these atoms, in their turn, are built up of two constituents, one of which is the electron, a particle of negative electricity whose mass is only 1/1800 of that of an atom of hydrogen, and the other a particle of positive electricity whose mass is practically identical with that of the same atom—the outcome, in short, of the collective work of Soddy, Rutherford, J. J. Thomson, Collie, Moseley and others—are pregnant facts which have completely altered the fundamental aspects of the science. Chemical philosophy has, in fact, now definitely entered on a new phase.

Looking back over the past, some indications of the coming change might have been perceived wholly unconnected, of course, with the recent experimental work which has served to ratify it. In a short paper entitled 'Speculative Ideas respecting the Constitution of Matter,' originally published in 1863, Graham conceived that the various kinds of matter, now recognised as different elementary substances, may possess one and the same ultimate or atomic molecule existing in different conditions of movement. This idea, in its essence, may be said to be as old as the time of Leucippus. To Graham as to Leucip-

pus 'the action of the atom as one substance taking various forms by combinations unlimited, was enough to account for all the phenomena of the world. By separation and union with constant motion all things could be done.' But Graham developed the conception by independent thought, and in the light of experimentally ascertained knowledge which the world owes to his labours. He might have been cognisant of the speculations of the Greeks, but there is no evidence that he was knowingly influenced by them. In his paper Graham uses the terms atom and molecule if not exactly in the same sense that modern teaching demands, yet very differently from that hitherto required by the limitations of contemporary chemical doctrine. He conceives of a lower order of atoms than the chemical atom of Dalton, and founds on his conception an explanation of chemical combination based upon a fixed combining measure, which he terms the *metron*, its relative weight being one for hydrogen, sixteen for oxygen, and so on with the other so-called 'elements.' Graham, in fact, like Davy before him, never committed himself to a belief in the indivisibility of the Daltonian atom. The original atom may, he thought, be far down.

The idea of a primordial ylé, or of the essential unity of matter, has persisted throughout the ages, and, in spite of much experimental work, some of it of the highest order, which was thought to have demolished it, it has survived, revivified and supported by analogies and arguments drawn from every field of natural inquiry. This idea of course was at the basis of the hypothesis of Prout, but which, even as modified by Dumas, was held to be refuted by the monumental work of Stas. But, as pointed out by Marignac and Dumas, anyone who will impartially look at the facts can hardly escape the feeling that there must be some reason for the frequent recurrence of atomic weights differing by so little from the numbers required by the law which the work of Stas was supposed to disprove. The more exact study within recent years of the methods of determining atomic weights, the great improvement in experimental appliances and technique, combined with a more rigorous standard of accuracy demanded by a general recognition of the far-reaching importance of an exact knowledge of these physical constants, has resulted in intensifying the belief that some natural law must be at the basis of the fact that so many of the most carefully determined atomic weights on the oxygen standard are whole numbers. Nevertheless there were well authenticated exceptions which seemed to invalidate its universality. The proved fact that a so-called element may be a mixture of isotopes—substances of the same chemical attributes but of varying atomic weight—has thrown new light on the question. It is now recognised that the fractional values independently established in the case of any one element by the most accurate experimental work of various investigators are, in effect, 'statistical quantities' dependent upon a mixture of isotopes. This result, indeed, is a necessary corollary of modern conceptions of the inner mechanism of

the atom. The theory that all elementary atoms are composed of helium atoms, or of helium and hydrogen atoms, may be regarded as an extension of Prout's hypothesis, with, however, this important distinction, that whereas Prout's hypothesis was at best a surmise, with little, and that little only weak, experimental evidence to support it, the new theory is directly deduced from well-established facts. The hydrogen isotope H_3, first detected by J. J. Thomson, of which the existence has been confirmed by Aston, would seem to be an integral part of atomic structure. Rutherford, by the disruption of oxygen and nitrogen has also isolated a substance of mass 3 which enters into the structure of atomic nuclei, but which he regards as an isotope of helium, which itself is built up of four hydrogen nuclei together with two cementing electrons. The atomic nuclei of elements of even atomic number would appear to be composed of helium nuclei only, or of helium nuclei with cementing electrons; whereas those of elements of odd atomic number are made up of helium and hydrogen nuclei together with cementing electrons. In the case of the lighter elements of the latter class the number of hydrogen nuclei associated with the helium nuclei is invariably three, except in that of nitrogen where it is two. The frequent occurrence of this group of three hydrogen nuclei indicates that it is structurally an isotope of hydrogen with an atomic weight of three and nuclear charge of one. It is surmised that it is identical with the hypothetical 'nebulium' from which our 'elements' are held by astro-physicists to be originally produced in the stars through hydrogen and helium.

These results are of extraordinary interest as bearing on the question of the essential unity of matter and the mode of genesis of the elements. Members of the British Association may recall the suggestive address on this subject of the late Sir William Crookes, delivered to the Chemical Section at the Birmingham meeting of 1886, in which he questioned whether there is absolute uniformity in the mass of the atoms of a chemical element, as postulated by Dalton. He thought, with Marignac and Schutzenberger, who had previously raised the same doubt, that it was not improbable that what we term an atomic weight merely represents a mean value around which the actual weights of the atoms vary within narrow limits, or, in other words, that the mean mass is 'a statistical constant of great stability.' No valid experimental evidence in support of this surmise was or could be offered at the time it was uttered. Maxwell pointed out that the phenomena of gaseous diffusion, as then ascertained, would seem to negative the supposition. If hydrogen, for example, were composed of atoms of varying mass it should be possible to separate the lighter from the heavier atoms by diffusion through a porous septum. 'As no chemist,' said Maxwell, 'has yet obtained specimens of hydrogen differing in this way from other specimens, we conclude that all the molecules of hydrogen are of sensibly the same mass, and not merely that their mean mass is a

statistical constant of great stability.'[1] But against this it may be doubted whether any chemist had ever made experiments sufficiently precise to solve this point.

The work of Sir Norman Lockyer on the spectroscopic evidence for the dissociation of 'elementary' matter at transcendental temperatures, and the possible synthetic intro-stellar production of elements, through the helium of which he originally detected the existence, will also find its due place in the history of this new philosophy.

Sir J. J. Thomson was the first to afford direct evidence that the atoms of an element, if not exactly of the same mass, were at least approximately so, by his method of analysis of positive rays. By an extension of this method Mr. F. W. Aston has succeeded in showing that a number of elements are in reality mixtures of isotopes. It has been proved, for example, that neon, which has a mean atomic weight of about 20 and .2 consists of two isotopes having the atomic weights respectively of 20 and 22, mixed in the proportion of 90 per cent. of the former with 10 per cent. of the latter. By fractional diffusion through a porous septum an apparent difference of density of 0.7 per cent. between the lightest and heaviest fractions was obtained. The kind of experiment which Maxwell imagined proved the invariability of the hydrogen atom has sufficed to show the converse in the case of neon.

The element chlorine has had its atomic weight repeatedly determined, and, for special reasons, with the highest attainable accuracy. On the oxygen standard it is 35.46, and this value is accurate to the second decimal place. All attempts to prove that it is a whole number—35 or 36—have failed. When, however, the gas is analysed by the same method as that used in the case of neon it is found to consist of at least two isotopes of relative mass 35 and 37. There is no evidence whatever of an individual substance having the atomic weight 35.46. Hence chlorine is to be regarded as a complex element consisting of two principal isotopes of atomic weights 35 and 37 present in such proportion as to afford the mean mass 35.46. The atomic weight of chlorine has been so frequently determined by various observers and by various methods with practically identical results that it seems difficult to believe that it consists of isotopes present in definite and invariable proportion. Mr. Aston meets this objection by pointing out that all the accurate determinations have been made with chlorine derived originally from the same source, the sea, which has been perfectly mixed for æons. If samples of the element could be obtained from some other original source it is possible that other values of atomic weight would be obtained, exactly as in the case of lead in which the existence of isotopes in the metal found in various radioactive minerals was first conclusively established.

Argon, which has an atomic weight of 39.88, was found to consist

[1] Clerk-Maxwell, Art. 'Atom,' *Ency. Brit.* 9th Ed.

mainly of an isotope having an atomic weight of 40, associated to the extent of about 3 per cent., with an isotope of atomic weight 36. Krypton and xenon are far more complex. The former would appear to consist of six isotopes, 78, 80, 82, 83, 84, 86; the latter of five isotopes, 129, 131, 132, 134, 136.

Fluorine is a simple element of atomic weight 19. Bromine consists of equal quantities of two isotopes, 79 and 81. Iodine, on the contrary, would appear to be a simple element of atomic weight 127. The case of tellurium is of special interest in view of its periodic relation to iodine, but the results of its examination up to the present are indefinite.

Boron and silicon are complex elements, each consisting of two isotopes, 10 and 11, and 28 and 29, respectively.

Sulphur, phosphorus, and arsenic are apparently simple elements. Their accepted atomic weights are practically integers.

All this work is so recent that there has been little opportunity, as yet, of extending it to any considerable number of the metallic elements. These, as will be obvious from the nature of the methods employed, present special difficulties. It is, however, highly probable that mercury is a mixed element consisting of many isotopes. These have been partially separated by Brönsted and Hervesy by fractional distillation at very low pressures, and have been shown to vary very slightly in density. Lithium is found to consist of two isotopes, 6 and 7. Sodium is simple, potassium and rubidium are complex, each of the two latter elements consisting, apparently, of two isotopes. The accepted atomic weight of cæsium, 132.81, would indicate complexity, but the mass spectrum shows only one line at 133. Should this be confirmed cæsium would afford an excellent test case. The accepted value for the atomic weight is sufficiently far removed from a whole number to render further investigation desirable.

This imperfect summary of Mr. Aston's work is mainly based upon the account he recently gave to the Chemical Society. At the close of his lecture he pointed out the significance of the results in relation to the periodic law. It is clear that the order of the chemical or 'mean' atomic weights in the periodic table has no practical significance; anomalous cases such as argon and potassium are simply due to the relative proportions of their heavier and lighter isotopes. This does not necessarily invalidate or even weaken the periodic law which still remains the expression of a great natural truth. That the expression as Mendeléeff left it is imperfect has long been recognised. The new light we have now gained has gone far to clear up much that was anomalous, especially Moseley's discovery that the real sequence is the atomic number, not the atomic weight. This is one more illustration of the fact that science advances by additions to its beliefs rather than by fundamental or revolutionary changes in them.

The bearing of the electronic theory of matter, too, on Prout's discarded hypothesis that the atoms of all elements were themselves built

up of a primordial atom—his *protyle* which he regarded as probably identical with hydrogen—is too obvious to need pointing out. In a sense Prout's hypothesis may be said to be now re-established, but with this essential modification—the primordial atoms he imagined are complex and are of two kinds—atoms of positive and negative electricity—respectively known as protons and electrons. These, in Mr. Aston's words, are the standard bricks that nature employs in her operations of element building.

The true value of any theory consists in its comprehensiveness and sufficiency. As applied to chemistry, this theory of 'the inner mechanism of the atom' must explain all its phenomena. We owe to Sir J. J. Thomson its extension to the explanation of the periodic law, the atomic number of an element, and of that varying power of chemical combination in an element we term valency. This explanation I give substantially in his own words. The number of electrons in an atom of the different elements has now been determined, and has been found to be equal to the atomic number of the element, that is to the position which the element occupies in the series when the elements are arranged in the order of their atomic weights. We know now the nature and quantity of the materials of which the atoms are made up. The properties of the atom will depend not only upon these factors but also upon the way in which the electrons are arranged in the atom. This arrangement will depend on the forces between the electrons themselves and also on those between the electrons and the positive charges or protons. One arrangement which naturally suggested itself is that the positive charges should be at the centre with the negative electrons around it on the surface of a sphere. Mathematical investigation shows that this is a possible arrangement if the electrons on the sphere are not too crowded. The mutual repulsion of the electrons resents overcrowding, and Sir J. J. Thomson has shown that when there are more than a certain number of electrons on the sphere, the attraction of a positive charge, limited as in the case of the atom in magnitude to the sum of the charges on the electrons, is not able to keep the electrons in stable equilibrium on the sphere, the layer of electrons explodes and a new arrangement is formed. The number of electrons which can be accommodated on the outer layer will depend upon the law of force between the positive charge and the electrons. Sir J. J. Thomson has shown that this number will be eight with a law of force of a simple type.

To show the bearing of this result as affording an explanation of the periodic law, let us, to begin with, take the case of the atom of lithium, which is supposed to have one electron in the outer layer. As each element has one more free electron in its atom than its predecessor, glucinum, the element next in succession to lithium, will have two electrons in the outer layer of its atom, boron will have three, carbon four, nitrogen five, oxygen six, fluorine seven and neon eight. As there cannot be more than eight electrons in the outer layer, the additional

electron in the atom of the next element, sodium, cannot find room in the same layer as the other electrons, but will go outside, and thus the atom of sodium, like that of lithium, will have one electron in its outer layer. The additional electron, in the atom of the next element, magnesium, will join this, and the atom of magnesium, like that of glucinum, will have two electrons in the outer layer. Again, aluminum, like boron, will have three; silicon, like carbon, four; phosphorus, like nitrogen, five; sulphur, like oxygen, six; chlorine, like fluorine, seven; and argon, like neon, eight. The sequence will then begin again. Thus the number of electrons, one, two, three, up to eight in the outer layer of the atom, will recur periodically as we proceed from one element to another in the order of their atomic weights, so that any property of an element which depends on the number of electrons in the outer layer of its atom will also recur periodically, which is precisely that remarkable property of the elements which is expressed by the periodic law of Mendeléeff, or the law of octaves of Newlands.

The valency of the elements, like their periodicity, is a consequence of the principle that equilibrium becomes unstable when there are more than eight electrons in the outer layer of the atom. For on this view the chemical combination between two atoms, A and B, consists in the electrons of A getting linked up with those of B. Consider an atom like that of neon, which has already eight electrons in its outer layer; it cannot find room for any more, so that no atoms can be linked to it, and thus it cannot form any compounds. Now take an atom of fluorine, which has seven electrons in its outer layer; it can find room for one, but only one, electron, so that it can unite with one, but not with more than one, atom of an element like hydrogen, which has one electron in the outer layer. Fluorine, accordingly, is monovalent. The oxygen atom has six electrons; it has, therefore, room for two more, and so can link up with two atoms of hydrogen: hence oxygen is divalent. Similarly nitrogen, which has five electrons and three vacant places, will be trivalent, and so on. On this view an element should have two valencies, the sum of the two being equal to eight. Thus, to take oxygen as an example, it has only two vacant places, and so can only find room for the electrons of two atoms; it has, however, six electrons available for filling up the vacant places in other atoms, and as there is only one vacancy to be filled in a fluorine atom the electrons in an oxygen atom could fill up the vacancies in six fluorine atoms, and thereby attach these atoms to it. A fluoride of oxygen of this composition remains to be discovered, but its analogue, SF_6, first made known by Moissan, is a compound of this type. The existence of two valencies for an element is in accordance with views put forward some time ago by Abegg and Bödlander. Professor Lewis and Mr. Irving Langmuir have developed, with great ingenuity and success, the consequences which follow from the hypothesis that an octet of electrons surrounds the atoms in chemical compounds.

The term 'atomic weight' has thus acquired for the chemist an alto-

gether new and much wider significance. It has long been recognised that it has a far deeper import than as a constant useful in chemical arithmetic. For the ordinary purposes of quantitative analysis, of technology, and of trade, these constants may be said to be now known with sufficient accuracy. But in view of their bearing on the great problem of the essential nature of matter and on the 'superlatively grand question, What is the inner mechanism of the atom?' they become of supreme importance. Their determination and study must now be approached from entirely new standpoints and by the conjoint action of chemists and physicists. The existence of isotopes has enormously widened the horizon. At first sight it would appear that we should require to know as many atomic weights as there are isotopes, and the chemist may well be appalled at such a prospect. All sorts of difficulties start up to affright him, such as the present impossibility of isolating isotopes in a state of individuality, their possible instability, and the inability of his quantitative methods to establish accurately the relatively small differences to be anticipated. All this would seem to make for complexity. On the other hand, it may eventually tend towards simplification. If, with the aid of the physicist we can unravel the nature and configuration of the atom of any particular element, determine the number and relative arrangement of the constituent protons and electrons, it may be possible to arrive at the atomic weight by simple calculation, on the assumption that the integer rule is mathematically valid. This, however, is almost certainly not the case, owing to the influence of 'packing.' The little differences, in fact, may make all the difference. The case is analogous to that of the so-called gaseous laws in which the departures from their mathematical expression have been the means of elucidating the physical constitution of the gases and of throwing light upon such variations in their behaviour as have been observed to occur. There would appear, therefore, ample scope for the chemist in determining with the highest attainable accuracy the departures from the whole-number rule, since it is evident that much depends upon their exact extent.

These considerations have already engaged the attention of chemists. For some years past, a small international committee, originally appointed in 1903, has made and published an annual report in which they have noted such determinations of atomic weight as have been made during the year preceding each report, and they have from time to time made suggestions for the amendment of the tables of atomic weights, published in text-books and chemical journals, and in use in chemical laboratories. In view of recent developments, the time has now arrived when the work of this international committee must be reorganised and its aims and functions extended. The mode in which this should be done has been discussed at the meeting in Brussels, in June last, of the International Union of Chemistry Pure and Applied, and has resulted in strengthening the constitution of the committee and in a wide extension of its scope.

The crisis through which we have recently passed has had a profound effect upon the world. The spectacle of the most cultured and most highly developed peoples on this earth, armed with every offensive appliance which science and the inventive skill and ingenuity of men could suggest, in the throes of a death struggle must have made the angels weep. That dreadful harvest of death is past, but the aftermath remains. Some of it is evil, and the evil will persist for, it may be, generations. There is, however, an element of good in it, and the good, we trust, will develop and increase with increase of years. The whole complexion of the world—material, social, economic, political, moral, spiritual—has been changed, in certain aspects immediately for the worse, in others prospectively for the better It behoves us, then, as a nation to pay heed to the lessons of the war.

The theme is far too complicated to be treated adequately within the limits of such an address as this. But there are some aspects of it germane to the objects of this association, and I venture, therefore, in the time that remains to me, to bring them to your notice.

The Great War differed from all previous internecine struggles in the extent to which organised science was invoked and systematically applied in its prosecution. In its later phases, indeed, success became largely a question as to which of the great contending parties could most rapidly and most effectively bring its resources to their aid. The chief protagonists had been in the forefront of scientific progress for centuries, and had an accumulated experience of the manifold applications of science in practically every department of human activity that could have any possible relation to the conduct of war. The military class in every country is probably the most conservative of all the professions and the slowest to depart from tradition. But when nations are at grips, and they realise that their very existence is threatened, every agency that may tend to cripple the adversary is apt to be resorted to—no matter how far it departs from the customs and conventions of war. This is more certain to be the case if the struggle is protracted. We have witnessed this fact in the course of the late War. Those who, realising that in the present imperfect stage of civilisation, wars are inevitable, and yet strove to minimise their horrors, and who formulated the Hague Convention of 1899, were well aware how these horrors might be enormously intensified by the applications of scientific knowledge, and especially of chemistry. Nothing shocked the conscience of the civilised world more than Germany's cynical disregard of the undertaking into which she had entered with other nations in regard, for instance, to the use of lethal gas in warfare. The nation that treacherously violated the Treaty of Belgium, and even applauded the action, might be expected to have no scruples in repudiating her obligations under the Hague Convention. April 25, 1915, which saw the clouds of the asphyxiating chlorine slowly wafted from the German trenches towards the lines of the Allies, witnessed one of the most

bestial episodes in the history of the Great War. The world stood aghast at such a spectacle of barbarism. German *Kultur* apparently had absolutely no ethical value. Poisoned weapons are employed by savages, and noxious gas had been used in Eastern warfare in early times, but its use was hitherto unknown among European nations. How it originated among the Germans—whether by the direct unprompted action of the Higher Command, or, as is more probable, at the instance of persons connected with the great manufacturing concerns in Rhineland, has, so far as I know, not transpired. It was not so used in the earlier stages of the War, even when it had become a war of position. It is notorious that the great chemical manufacturing establishments of Germany had been, for years previously, sedulously linked up in the service of the war which Germany was deliberately planning—probably, in the first instance, mainly for the supply of munitions and medicaments. We may suppose that it was the tenacity of our troops, and the failure of repeated attempts to dislodge them by direct attack, that led to the employment of such foul methods. Be this as it may, these methods became part of the settled practice of our enemies, and during the three succeeding years, that is from April 1915, to September 1918, no fewer than eighteen different forms of poison—gases, liquids and solids—were employed by the Germans. On the principle of Vespasian's law, reprisals became inevitable, and for the greater part of three years we had the sorry spectacle of the leading nations of the world flinging the most deadly products at one another that chemical knowledge could suggest and technical skill contrive. Warfare, it would seem, has now definitely entered upon a new phase. The horrors which the Hague Convention saw were imminent, and from which they strove to protect humanity, are now, apparently, by the example and initiative of Germany, to become part of the established procedure of war. Civilisation protests against a step so retrograde. Surely comity among nations should be adequate to arrest it. If the League of Nations is vested with any real power, it should be possible for it to devise the means, and to ensure their successful application. The failure of the Hague Convention is no sufficient reason for despair. The moral sense of the civilised world is not so dulled but that, if roused, it can make its influence prevail. And steps should be taken without delay to make that influence supreme, and all the more so that there are agencies at work which would seek to perpetuate such methods as a recognised procedure of war. The case for what is called chemical warfare has not wanted for advocates. It is argued that poison gas is far less fatal and far less cruel than any other instrument of war. It has been stated that 'amongst the "mustard gas" casualties the deaths were less than 2 per cent., and when death did not ensue complete recovery generally ultimately resulted. . . . Other materials of chemical warfare in use at the armistice do not kill at all; they produce casualties which, after six weeks in hospital, are discharged practically

without permanent hurt.' It has been argued that, as a method of conducting war, poison-gas is more humane than preventive medicine. Preventive medicine has increased the unit dimension of an army, free from epidemic and communicable disease, from 100,000 men to a million. 'Preventive medicine has made it possible to maintain 20,000,000 men under arms and abnormally free from disease, and so provided greater scope for the killing activities of the other military weapons. . . . Whilst the surprise effects of chemical warfare aroused anger as being contrary to military tradition, they were minute compared with those of preventive medicine. The former slew its thousands, whilst the latter slew its millions and is still reaping the harvest.' This argument carries no conviction. Poison gas is not merely contrary to European military tradition; it is repugnant to the right feeling of civilised humanity. It in no wise displaces or supplants existing instruments of war, but creates a new kind of weapon, of limitless power and deadliness. 'Mustard gas' may be a comparatively innocuous product as lethal substances go. It certainly was not intended to be such by our enemies. Nor, presumably, were the Allies any more considerate when they retaliated with it. Its effects, indeed were sufficient terrible to destroy the German *morale*. The knowledge that the Allies were preparing to employ it to an almost boundless extent was one of the factors that determined our enemies to sue for the armistice. But if poisonous chemicals are henceforth to be regarded as a regular means of offence in warfare, is it at all likely that their use will be confined to 'mustard gas,' or indeed to any other of the various substances which were employed up to the date of the armistice? To one who, after the peace, inquired in Germany concerning the German methods of making 'mustard gas,' the reply was:—'Why are you worrying about this when you know perfectly well that this is not the gas we shall use in the next war?'

I hold no brief for preventive medicine, which is well able to fight its own case. I would only say that it is the legitimate business of preventive medicine to preserve by all known means the health of any body of men, however large or small, committed to its care. It is not to its discredit if, by knowledge and skill, the numbers so maintained run into millions instead of being limited to thousands. On the other hand, 'an educated public opinion' will refuse to give credit to any body of scientific men who employ their talents in devising means to develop and perpetuate a mode of warfare which is abhorrent to the higher instinct of humanity.

This association, I trust, will set its face against the continued degradation of science in thus augmenting the horrors of war. It could have no loftier task than to use its great influence in arresting a course which is the very negation of civilisation.

THE LABORATORY OF THE LIVING ORGANISM

By Dr. M. O. FORSTER, F.R.S.

PRESIDENT OF THE CHEMICAL SECTION

AMONGST the many sources of pleasure to be found in contemplating the wonders of the universe, and denied to those untrained in scientific principles, is an appreciation of infra-minute quantities of matter. It may be urged by some that within the limits of vision imposed by telescope and microscope, ample material exists to satisfy the curiosity of all reasonable people, but the appetite of scientific inquiry is insatiable, and chemistry alone, organic, inorganic, and physical, offers an instrument by which the investigation of basal changes may be carried to regions beyond those encompassed by the astronomer and the microscopist.

It is not within the purpose of this address to survey that revolution which is now taking place in the conception of atomic structure; contributions to this question will be made in our later proceedings and will be followed with deep interest by all members of the section. Fortunately for our mental balance the discoveries of the current century, whilst profoundly modifying the atomic imagery inherited from our predecessors, have not yet seriously disturbed the principles underlying systematic organic chemistry; but they emphasise in a forcible manner the intimate connection between different branches of science, because it is from the mathematical physicist that these new ideas have sprung. Their immediate value is to reaffirm the outstanding importance of borderline research and to stimulate interest in sub-microscopic matter.

This interest presents itself to the chemist very early in life and dominates his operations with such insistence as to become axiomatic. So much so that he regards the universe as a vast theatre in which atomic and molecular units assemble and interplay, the resulting patterns into which they fall depending on the physical conditions imposed by nature. This enables him to regard micro-organisms as co-practitioners of his craft, and the chemical achievements of these humble agents have continued to excite his admiration since they were revealed by Pasteur. The sixty years which have now elapsed are rich in contributions to that knowledge which comprises the science of micro-biochemistry, and in this province, as in so many others, we have to deplore the fact that the principal advances have been made in countries other than our own. On this ground, fortified by the intimate relation of the science to a number of important industries, A. Chaston Chapman, in a series of illuminating and attractive Cantor Lectures in December, 1920, iterated his plea of the previous year for the foundation of a National Institute of Industrial Micro-biology, whilst H. E. Armstrong, in Birmingham a few weeks later, addressed an appeal to the brewing industry, which, although taking the form of a memorial

lecture, is endowed with many lively features depicting in characteristic form the manner in which the problems of brewing chemistry should, in his opinion, be attacked.

Lamenting as we now do so bitterly the accompaniments and consequences of war, it is but natural to snatch at the slender compensations which it offers, and not the least among these must be recognised the stimulus which it gives to scientific inquiry. Pasteur's *Etudes sur la Bière* were inspired by the misfortunes which overtook his country in 1870-71, and the now well-known process of Connstein and Lüdecke for augmenting the production of glycerol from glucose was engendered by parallel circumstances. That acquaintance with the yeast-cell which was an outcome of the former event had, by the time of the latter discovery, ripened into a firm friendship, and those who slander the chemical activities of this genial fungus are defaming a potential benefactor. Equally culpable are those who ignore them. If children were encouraged to cherish the same intelligent sympathy with yeast-cells which they so willingly display towards domestic animals and silkworms, perhaps there would be fewer crazy dervishes to deny us the moderate use of honest malt-liquors and unsophisticated wines, fewer pitiable maniacs to complicate our social problems by habitual excess.

Exactly how the cell accomplishes its great adventure remains a puzzle, but many parts of the machinery have already been recognised. Proceeding from the discovery of zymase (1897), with passing reference to the support thus given by Buchner to Liebig's view of fermentation, Chapman emphasises the importance of contributions to the subject by Harden and W. J. Young, first in revealing the dual nature of zymase and the distinctive properties of its co-enzyme (1904), next in recognising the acceleration and total increase in fermentation produced by phosphates, consequent on the formation of a hexosediphosphate (1908).

In this connection it will be remembered that a pentose-phosphate is common to the four nucleotides from which yeast nucleic acid is elaborated. The stimulating effect developed by phosphates would not be operative if the cell were not provided with an instrument for hydrolysing the hexose-diphosphate as produced, and this is believed by Harden to be supplied in the form of an enzyme, hexosephosphatase, the operation of which completes a cycle. As to the stages of disruption which precede the appearance of alcohol and carbon dioxide, that marked by pyruvic acid is the one which is now most favoured. The transformation of pyruvic acid into acetaldehyde and carbon dioxide under the influence of a carboxylase, followed by the hydrogenation of aldehyde to alcohol, is a more acceptable course than any alternative based upon lactic acid. Moreover, Fernbach and Schoen (1920) have confirmed their previous demonstration (1914) of pyruvic acid formation by yeast during alcoholic fermentation.

The strict definition of chemical tasks allotted to yeasts, moulds, and bacteria suggests an elaborate system of microbial trades-unionism. E. C. Grey (1918) found that *Bacillus coli communis* will, in presence of calcium carbonate, completely ferment forty times its own weight of glucose in forty-eight hours, and later (1920) exhibited the threefold character of the changes involved which produce (1) lactic acid, (2) alcohol with acetic and succinic acids, (3) formic acid, carbon dioxide, and hydrogen. Still more recent extension of this inquiry by Grey and E. G. Young (1921) has shown that the course of such changes will depend on the previous experience of the microbe. When its immediate past history is anærobic, fermentation under anærobic conditions yields very little or no lactic acid and greatly diminishes the production of succinic acid, whilst acetic acid appears in its place; admission of oxygen during fermentation increases the formation of lactic, acetic, and succinic acids, diminishes the formation of hydrogen, carbon dioxide, and formic acid, but leaves the quantity of alcohol unchanged. The well-known oxidising effect of *Aspergillus niger* has been shown by J. N. Currie (1917) to proceed in three stages marked by citric acid, oxalic acid, and carbon dioxide, whilst Wehmer (1918) has described the condition under which citric acid and, principally, fumaric acid are produced by *Aspergillus fumaricus*, a mould also requiring oxygen for its purpose. The lactic bacteria are a numerous family and resemble those producing acetic acid in their venerable record of service to mankind, whilst among the most interesting of the parvenus are those responsible for the conversion of starch into butyl alcohol and acetone. Although preceded by Schardinger (1905), who discovered the ability of B. *macerans* to produce acetone with acetic and formic acids, but does not appear to have pursued the matter further, the process associated with the name of A. Fernbach, and the various modifications which have been introduced during the past ten years are those best known in this country, primarily because of the anticipated connection with synthetic rubber, and latterly on account of the acetone famine arising from the War. The King's Lynn factory was resuscitated and arrangements had just been completed for adapting spirit distilleries to application of the process when, owing to the shortage of raw material in 1916, operations were transferred to Canada and ultimately attained great success in the factory of British Acetones, Toronto.

Much illuminating material is to be found in the literature of 1919-20 dealing with this question in its technological and bacteriological aspects. Ingenuity has been displayed in attempting to explain the chemical mechanism of the process, the net result of which is to produce roughly twice as much butyl alcohol as acetone. The fermentation itself is preceded by saccharification of the starch, and in this respect the bacteria resemble those moulds which have lately been brought into the technical operation of starch-conversion, especially in

France. The amyloclastic property of certain moulds has been known from very early times, but its application to spirit manufacture is of recent growth and underlies the amylo-process which substitutes *Mucor Boulard* for malt in effecting saccharification. Further improvement on this procedure is claimed for *B. mesentericus*, which acts with great rapidity on grain which has been soaked in dilute alkali; it has the advantage of inferior proteolytic effect, thus diminishing the waste of nitrogenous matter in the raw material.

Reviewing all these circumstances we find that, just as the ranks of trades-union labour comprise every kind of handicraftsman, the practitioners of micro-biochemistry are divisible into producers of hydrogen, carbon dioxide, formic acid, acetaldehyde, ethyl alcohol, acetic, oxalic, and fumaric acids, acetone, dihydroxyacetone, glycerol, pyruvic, lactic, succinic and citric acids, butyl alcohol, butyric acid. Exhibiting somewhat greater elasticity in respect of overlapping tasks, they nevertheless go on strike if underfed or dissatisfied with their conditions; on the other hand, with sufficient nourishment and an agreeable temperature, these micro-trades-unionists display the unusual merit of working for twenty-four hours a day. One thing, however, they have consistently refused to do. Following his comparison of natural and synthetic monosaccharides towards different families of yeast (1894), Fischer and others have attempted to beguile unsuspecting microbes into acceptance of molecules which do not harmonise with their own enzymic asymmetry. Various *apéritifs* have been administered by skilled *chefs de cuisine*, but hitherto the little fellows have remained obdurate.

Beyond a placid acceptance of the more obvious benefits of sunshine, the great majority of educated people have no real conception of the sun's contribution to their existence. What proportion of those who daily use the metropolitan system of tube-railways, for instance, could trace the connection between their progress and the sun? Very moderate instruction comprising the elements of chemistry and energy would enable most of us to apprehend this modern wonder, contemplation of which might help to alleviate the distresses and exasperation of the crush-hours.

For many years past, the problem connected with solar influence which has most intrigued the chemist is to unfold the mechanism enabling green plants to assimilate nitrogen and carbon. Although atmospheric nitrogen has long been recognised as the ultimate supply of that element from which phyto-protoplasm is constructed, modern investigation has indicated as necessary a stage involving association of combined nitrogen with the soil prior to absorption of nitrogen compounds by the roots, with or without bacterial cooperation. Concurrently, the agency by which green plants assimilate carbon is believed to be chlorophyll, operating under solar influence by some such mechanism as has been indicated in a preceding section.

Somewhat revolutionary views on these two points have lately been expressed by Benjamin Moore, and require the strictest examination, not merely owing to the fundamental importance of an accurate solution being reached, but also on account of the stimulating and engaging manner in which he presents the problem. Unusual psychological features have been introduced. Moore's 'Biochemistry,' published three months ago, will be read attentively by many chemists, but the clarity of presentation and the happy sense of conviction which pervade its pages must not be allowed to deter independent inquirers from confirming or modifying his conclusions. The book assumes a novel biochemical aspect by describing the life-history of a research. The first two chapters, written before the experiments were begun, suggest the conditions in which the birth of life may have occurred, whilst their successors describe experiments which were conducted as a test of the speculations and are already receiving critical attention from others (e.g., Baly, Heilbron and Barker, Transactions of the Chemical Society, 1921, p. 1025).

It is with these experiments that we are, at the moment, most concerned. The earliest were directed toward the synthesis of simple organic materials by a transformation of light energy under the influence of inorganic colloids, and indicated that formaldehyde is produced when carbon dioxide passes into uranium or ferric hydroxide sols exposed to sunlight or the mercury arc lamp. Moore then declares that, although since the days of de Saussure (1804) chlorophyll has been regarded as the fundamental agent in the photosynthesis of living matter, there is no experimental evidence that the primary agent may not be contained in the colourless part of the chloroplast, chlorophyll thus being the result of a later synthetic stage. 'The function of the chlorophyll may be a protective one to the chloroplast when exposed to light, it may be a light screen as has been suggested by Pringsheim, or it may be concerned in condensations and polymerisations subsequent to the first act of synthesis with production of formaldehyde' (p. 55). In this connection it is significant that chlorosis of green plants will follow a deficiency of iron even in presence of sunlight (Molisch, 1892), and that a development of chlorophyll can be restored by supplying this deficiency, although iron is not a component of the chlorophyll molecule; moreover, green leaves etiolated by darkness and then exposed to light regain their chlorophyll, which is therefore itself a product arising from photosynthesis.

H. Thiele (1907) recorded the swift conversion of nitrate into nitrite by the rays from a mercury quartz lamp, whilst O. Baudisch (1910) observed that daylight effects the same change, and from allied observations was led (1911) to conclude that assimilation of nitrate and nitrite by green plants is a photochemical process. Moore found (1918) that in solutions of nitrate undergoing this reduction green leaves check the accumulation of nitrite, indicating their capacity to

absorb the more active compound. Proceeding from the hypothesis that one of the organisms arising earliest in the course of evolution must have possessed, united in a single cell, the dual function of assimilating both carbon and nitrogen, he inquired (1918) whether the simplest unicellular algæ may not also have this power. He satisfied himself that in absence of all sources of nitrogen excepting atmospheric, and in presence of carbon dioxide, the unicellular algæ can fix nitrogen, grow and form proteins by transformation of light energy; the rate of growth is accelerated by the presence of nitrites or oxides of nitrogen, the latter being supplied in gaseous form by the atmosphere. From experiments (1919) with green seaweed (*Enteromorpha compressus*), Moore concluded also that marine algæ assimilate carbon from the bicarbonates of calcium and magnesium present in sea-water, which thereby increases in alkalinity, and further convinced himself that the only source of nitrogen available to such growth is the atmosphere. A description of these experiments, which were carried out in conjunction with E. Whitley and T. A. Webster, has appeared also in the Proceedings of the Royal Society (1920 and 1921).

For the purpose of distinguishing between (1) the obsolete view of a vital force disconnected with such forms of energy as are exhibited by non-living transformers and (2) the existence in living cells of only such energy forms as are encountered in non-living systems, Moore uses the expression 'biotic energy' to represent that form of energy peculiar to living matter. 'The conception, in brief, is that biotic energy is just as closely, and no more, related to the various forms of energy existing apart from life, as these are to one another, and that in presence of the proper and adapted energy transformer, the living cell, it is capable of being formed from or converted into various of these other forms of energy, the law of conservation of energy being obeyed in the process just as it would be if an exchange were taking place between any two or more of the inorganic forms' (p. 128). The most characteristic feature of biotic energy, distinguishing it from all other forms, is the power which it confers upon the specialised transformer to proliferate.

In 'The Salvaging of Civilisation,' H. G. Wells has lately directed the attention of thoughtful people to the imperative need of reconstructing our outlook on life. Convinced that the state-motive which, throughout history, has intensified the self-motive must be replaced by a world-motive if the whole fabric of civilisation is not to crumble in ruins, he endeavours to substitute for a League of Nations the conception of a World State. In the judgment of many quite benevolent critics his essay in abstract thought lacks practical value because it underestimates the combative selfishness of individuals. Try to disguise it as one may, this quality is the one which has enabled men to emerge from savagery, to build up that most wonderful system of colonial organisation, the Roman Empire, and to shake off the barbaric

lethargy which engulfed Europe in the centuries following the fall of Rome. The real problem is how to harness this combative selfishness. To eradicate it seems impossible, and it has never been difficult to find glaring examples of its insistence among the apostles of eradication. Why cry for the moon? Is it not wiser to recognise this quality as an inherent human characteristic, and whether we brand it as a vice or applaud it as a virtue endeavour to bend it to the elevation of mankind? For it could so be bent. Nature ignored or misunderstood is the enemy of man; nature studied and controlled is his friend. If the attacking force of this combative selfishness could be directed, not towards the perpetuation of quarrels between different races of mankind, but against nature, a limitless field for patience, industry, ingenuity, imagination, scholarship, aggressiveness, rivalry, and acquisitiveness would present itself; a field in which the disappointment of baffled effort would not need to seek revenge in the destruction of our fellow-creatures: a field in which the profit from successful enterprise would automatically spread through all the communities. Surely it is the nature-motive, as distinct from the state-motive or the world-motive, which alone can salvage civilisation.

Before long, as history counts time, dire necessity will have impelled mankind to some such course. Already the straws are giving their proverbial indication. The demand for wheat by increasing populations, the rapidly diminishing supplies of timber, the wasteful ravages of insect pests, the less obvious, but more insidious depredations of our microscopic enemies, and the blood-curdling fact that a day must dawn when the last ton of coal and the last gallon of oil have been consumed, are all circumstances which, at present recognised by a small number of individuals comprising the scientific community, must inevitably thrust themselves upon mankind collectively. In the campaign which then will follow, chemistry must occupy a prominent place because it is this branch of science which deals with matter more intimately than any other, revealing its properties, its transformations, its application to existing needs, and its response to new demands. Yet the majority of our people are denied the elements of chemistry in their training, and thus grow to manhood without the slightest real understanding of their bodily processes and composition, of the wizardry by which living things contribute to their nourishment and to their æsthetic enjoyment of life.

It should not be impossible to bring into the general scheme of secondary education a sufficiency of chemical, physical, mechanical, and biological principles to render every boy and girl of sixteen possessing average intelligence at least accessible to an explanation of modern discoveries. One fallacy of the present system is to assume that relative proficiency in the inorganic branch must be attained before approaching organic chemistry. From the standpoint of correlating scholastic knowledge with the common experiences and contacts of daily

life this is quite illogical; from baby's milk to grandpa's Glaxo the most important things are organic, excepting water. Food (meat, carbohydrate, fat), clothes (cotton, silk, linen, wool), and shelter (wood) are organic, and the symbols for carbon, hydrogen, oxygen and nitrogen can be made the basis of skeleton representations of many fundamental things which happen to us in our daily lives without first explaining their position in the periodic table of all the elements. The curse of mankind is not labour, but waste; misdirection of time, of material, of opportunity, of humanity.

Realisation of such an ideal would people the ordered communities with a public alive to the verities, as distinct from irrelevancies of life, and apprehensive of the ultimate danger with which civilization is threatened. It would inoculate that public with a germ of the nature-motive, producing a condition which would reflect itself ultimately upon those entrusted with government. It would provide the mental and sympathetic background upon which the future truthseeker must work, long before he is implored by a terrified and despairing people to provide them with food and energy. Finally, it would give an unsuspected meaning and an unimagined grace to a hundred commonplace experiences. The quivering glint of massed bluebells in broken sunshine, the joyous radiance of young beech-leaves against the stately cedar, the perfume of hawthorn in the twilight, the florid majesty of rhododendron, the fragrant simplicity of lilac; periodically gladden the most careless heart and the least reverent spirit; but to the chemist they breathe an added message, the assurance that a new season of refreshment has dawned upon the world, and that those delicate syntheses, into the mystery of which it is his happy privilege to penetrate, once again are working their inimitable miracles in the laboratory of the living organism.

EXPERIMENTAL GEOLOGY

By Dr. J. S. FLETT, F.R.S.

PRESIDENT OF THE GEOLOGICAL SECTION

AMONG the citizens of Edinburgh in the closing years of the eighteenth century there was a brilliant little group of scientific, literary, and philosophical writers. These were the men who founded the Royal Society of Edinburgh in the year 1783, and many of their important papers appear in the early volumes of its Transactions. Among them were Adam Ferguson, the historian and philosopher; Black, the chemist who discovered carbonic acid and the latent heat of water; Hope, who proved the expansion of water on cooling; Clerk of Eldin, who made valuable advances in the theory of naval tactics, and his brother, Sir George Clerk; Hutton, the founder of modern geology;

and Sir James Hall, the experimental geologist. These men were all intimate friends keenly interested in one another's researches. Quite the most notable member of this group was Hutton, who, not mainly for his eminence in geology, but principally for his social gifts, his bonhomie, and his versatility, was regarded as the centre of the circle. Hutton showed an extraordinary combination of qualities. His father was Town Clerk of Edinburgh. After starting as an apprentice to a Writer to the Signet, he took up the study of medicine at the Universities of Edinburgh and Paris, and graduated at Leyden. He then became a farmer on his father's property in Berwickshire, and also carried on chemical manufactures in Leith in partnership with Mr. Davie. He studied methods of agriculture in England and elsewhere, and was an active supporter of the movement for improving Scottish agriculture by introducing the best methods of other countries. A burning enthusiast in geology, especially in the 'theory of the earth,' he travelled extensively in Scotland, England, and on the Continent making geological observations.

His interests were not confined to geology, for he wrote a treatise on metaphysics, which seems to have been more highly esteemed in his day than in ours, and in his last years he produced a work on agriculture which was never published. The manuscript of this work is now in the library of the Edinburgh Geological Society. He also made interesting contributions to meteorology. Hutton's writings are as obscure and involved as his conversation was clear and persuasive, and it is only from the accounts of his friends, and especially Playfair's 'Life of Hutton,' that we can really ascertain what manner of man he was.

It could easily have happened that when Hutton died his unreadable writings might have passed out of notice, to be rediscovered at a subsequent time, when their value could be better appreciated. But Playfair's 'Explanations of the Hutton Theory,' as attractive and convincing still as when it was originally published, established at once the true position of Hutton as one of the founders of geology. Sir James Hall undertook a different task; he determined to put Hutton's theories to the test of experiment, and in so doing he became the virtual founder of modern experimental geology. It is my purpose in this address to show what were the problems that Hall attacked, by what methods he attempted to solve them, and what were his results. I shall also consider how far the progress of science has carried us since Hall's time regarding this department of geological science.

Hutton was a friend of Hall's father: they were proprietors of adjacent estates in the county of Berwick, and much interested in the improved practice of agriculture, and though the elder Hall (Sir John Hall of Dunglass) has apparently left no scientific writings, he was one of those who were famiiliar with Hutton's theories and a member of

the social group in which Hutton moved. Sir James Hall was the eldest son; born in 1761, he succeeded to the estate on his father's death in 1776. Educated first at Cambridge and then at Edinburgh University, at an early age he became fascinated by Hutton's personality, though repelled by his theories. He tells us how for three years he argued with Hutton daily, rejecting his principles. Hutton prevailed in the long run, and Sir James Hall was convinced. Hall's objection to Hutton's theories is not difficult to understand, though he has not himself explained it. The world was sick of discussions on cosmogony in which rival theorists appealed to well-known facts as proof of the most extravagant speculations. Serious-minded men were losing interest in these proceedings. The Geological Society of London was founded in 1807, and one of its objects is stated to be the avoidance of speculation and the patient accumulation of facts. No doubt Hall also was greatly influenced by the discoveries that Black and Hope had made by pure experimental investigation. His bent of mind was towards chemical, physical, and experimental work, while Hutton was not only a geologist but also a metaphysician.

Foreign travel was then an essential part of the education of a Scottish gentleman, and the connection between France, Holland, and Scotland was closer than it is today. Hall travelled widely; in his travels two subjects seem to have especially engrossed him. One was architecture, on which he wrote a treatise which was published in 1813 and is now forgotten. The other was geology. He visited the Alps, Italy, and Sicily. In Switzerland he may have met De Saussure and discussed with him the most recent theories of their time regarding metamorphism and the origin of granites, schists, and gneisses. In Italy and Sicily one of his objects was to observe the phenomena of active volcanoes, and to put to the test of facts the theories of Werner and of the Scottish school regarding the origin of basalt, whinstone, trap, and the older volcanic rocks of the earth's crust. At Vesuvius he made his famous observation of the dykes that rise nearly vertically through the crater wall of Somma, which he held to prove the ascent of molten magma from below through fissures to the surface. This was in opposition to the interpretation of the Wernerians, who regarded them as filled from above by aqueous sediments, and Hall's conclusions, which were strikingly novel at the time, have been abundantly confirmed.

We obtain a pleasant glimpse of Hall's life in Berwickshire in the account of his visit with Hutton and Playfair to Siccar Point in the year 1788. The start was made from Dunglass, where probably the party had spent the night. The great conglomerates of the Upper Old Red Sandstone of that district had much impressed Hutton. He saw in them the evidence of new worlds built out of the ruins of the old, with no sign of a beginning and no prospect of an end—a thesis which

was one of the corner-stones of his 'Theory of the Earth.' No doubt Hall knew or suspected that in the cliff-exposures at Siccar Point, where the Old Red rests upon the Silurian, there was evidence which would put this dogma to a critical test.

Hall's first experiments were begun in the year 1790, his object being to ascertain whether crystallisation would take place in a molten lava which was allowed to cool slowly. It was generally believed that the results of fusion of rocks and earths were in all cases vitreous, but glassmakers knew that if glass was very slowly cooled, as sometimes happened when a glass furnace burst, the whole mass assumed a stony appearance. An instance of this had come under Hall's notice in a glassworks in Leith, and its application to geology was clear. Hutton taught that even such highly crystalline rocks as granite had been completely fused at the time of their injection, and their coarse crystallisation was mainly due to slow cooling.

For the purpose of his experiments Hall selected certain whinstones of the neighborhood of Edinburgh, such as the dolerites of the Dean, Salisbury Crags, Edinburgh Castle, the summit of Arthur's Seat, and Duddingston; but he also used lava from Vesuvius, Etna, and Iceland. He made choice of graphite crucibles, and conducted his experiments in the reverberatory furnace of an ironfoundry belonging to Mr. Barker. As had been shown by Spallanzani, to whose experiments Hall does not refer, lavas are easily fusible under these conditions. Hall had no difficulty in melting the whinstones and obtaining completely glassy products by rapid cooling. He now proceeded to crystallise the glass by melting it again, transferring it from the furnace to a large open fire, where it was kept surrounded by burning coals for many hours, and thereafter very slowly cooled by allowing the fire to die out. He succeeded in obtaining a stony mass in which crystals of felspar and other minerals could be clearly seen. Some of his specimens were considered to be very similar in appearance to the dolerites on which his experiments were made.

The only means of measuring furnace temperatures available at that time were the pyrometers which had recently been invented by Wedgwood. Hall found that a temperature of 28 to 30 Wedgwood yielded satisfactory results. This seems to be about the melting-point of copper, approximately 1000° C.

Whether by design or accident, Hall chose for his experiments precisely the rocks which were most suitable for his purpose. If granite had been selected no definite results would have been obtained. De Saussure had already made fusion experiments on granite. Ninety years afterwards the problem was completely solved by Fouqué and Lévy, who used a gas furnace and a nitrogen thermometer. They found that it was possible to obtain either porphyritic or ophitic structure by modifying the conditions, and that the minerals had exactly

the characters of those of the igneous rocks. Some of Hall's recrystallised dolerites were examined microscopically by Fouqué and Lévy, and, as might be expected, they proved to be only partly crystallised, showing skeleton crystals of olivine and felspar with grains of iron ore in a glassy base.

Some curious observations made by Hall in his experimental work were also confirmed by Fouqué and Lévy. The crystalline whinstones were more difficult to melt than the glasses which were obtained from them, and the glass crystallised best when kept for a time at a temperature a little above its softening point. It is not possible to assign a definite melting-point to the Scottish whinstones with which Hall worked. Many of them contain zeolites, which fuse readily. Minerals are also present that decompose on heating, such as calcite, dolomite, chlorite, and serpentine. The whole process is very complex, and probably takes place by several stages not sharply distinct. Similarly the glasses cannot be said to have a melting-point. They are really super-cooled liquids. A full explanation of what took place in Hall's crucibles cannot be given at the present day, but there is no room for doubt that his experiments were good and his inferences accurate. His friend Kennedy, who had recently discovered the presence of alkalis in igneous rocks, furnished valuable support to Hall's conclusions by showing that the chemical composition of whinstone and of basalt were substantially identical.

Apparently the results of Hall's work were not received with unmixed approbation. Hutton was distinctly uneasy, and it has been suggested that he feared if experimental work turned out unsuccessful it might bring his theories into discredit. The Wernerians frankly scoffed; they preferred argument to experiment, and the endless discussion went on. Gregory Watt repeated Hall's experiments by fusing Clee Hill dolerite, a hundredweight or two at a time, in a blast-furnace. But there can be no doubt that among those who were not already committed to the principles of Werner the new evidence produced a strong impression, and helped to widen the circle of Hutton's supporters.

Hall's most famous experiments were on the effect of heat combined with pressure on carbonate of lime. The problem was, Can powdered chalk be converted into firm limestone or into marble by heating it in a confined space? In this case Hutton's theories were in apparent conflict with experimental facts; from general observations he held it proved that heat and pressure had consolidated limestones and converted them into marbles. It was well known, of course, that limestone, when heated in an open vessel, was transformed into quicklime, and Black had shown that the explanation was that carbonic acid had been expelled in the form of gas.

The experiments were begun in 1790, but deferred till 1798 after

Hutton's death. Hutton quite openly disapproved of experiments. His famous apophthegm has often been quoted about those who 'judge of the great operations of the mineral kingdom by kindling a fire and looking in the bottom of a crucible.' In deference to the feelings of his master and his father's friend, Sir James Hall, with admirable self-restraint, decided not to undertake experimental investigations in opposition to Hutton's expressed opinion. With a few month's interruption in 1800 they were continued till 1805. A preliminary account of the results was communicated to the Royal Society of Edinburgh on August 30, 1804, and the final papers submitted on June 3, 1805. Hall states that he made over 500 individual experiments and destroyed vast numbers of gun-barrels in this research.

The method adopted was to use a muffle-furnace burning coal or coke and built of brick. No blast seems to have been employed. The chalk-powder was enclosed in a gun-barrel cut off near the touch-hole and welded into a firm mass of iron. The other end of the barrel could be kept cool by applying wet cloths, and as it was not in the furnace its temperature was always comparatively low. Various methods of plugging the barrel were adopted; at first he used clay, sometimes with powdered flint. Subsequently a fusible metal which melted at a temperature below that of boiling water was almost always preferred. Borax glass with sand was used in some of the experiments, but it was liable to cracking when allowed to cool, and consequently was not always gas-tight. It was essential, of course, that in sealing up the gun-barrel, and in subsequently removing the plug, the temperatures should never be so high as to have any sensible effect on the powdered chalk or limestone. Hall tried vessels with screwed stoppers or lids at first, but never found them satisfactory.

In the gun-barrel there was always a certain amount of air enclosed with the chalk. Very early in the experiments it was shown that if no air-space was provided the fusible metal burst the barrel. No means was found to measure the size of the air-space accurately, but approximately it was equal to that of the powdered chalk used in the experiment. If the air-space was too large, or if there was an escape of gas, part of the chalk was converted into lime.

As each experiment lasted several hours the temperature of the chalk was approximately equal to that of the part of the muffle in which it was placed. Pyrometry was as yet in its infancy. Wedgwood had invented pyrometric cones and Hall had heard of them, but apparently at first he was not in possession of a set. He made his own cones as nearly similar as possible to those of Wedgwood, and subsequently obtaining a set of Wedgwood's cones he standardized his own by comparison with them. His gun-barrels of Swedish and Russian iron ('Old Sable') were softened, but seldom gave way except when the internal pressures were of a high order. Some of the gun-barrels seem to have

been used for many experiments without failure occurring. As Hall made his own pyrometric cones, and we have no details of their composition and the method of preparation, it is not possible to do more than guess at the temperatures to which his powdered lime and chalk were exposed. There is no doubt that by constant practice and careful observation he was able to regulate the temperature within fairly wide limits.

Hall began his experiments as already stated in 1798. They were interrupted for about a year (March 1800 to March 1801), and on March 31, 1801, he had obtained a considerable measure of success. A charge of forty grains of powdered chalk was converted into a firm granular crystalline mass of limestone. The loss on weighing was approximately 10 per cent. Another charge of eighty grains was converted into marble (on March 3, 1801), with a loss of approximately 5 per cent., and the crystalline mass showed distinct rhombohedral cleavage.

Though it cannot be said that his success was easily won he was by no means satisfied, and for another four years he continued his researches. Many different methods were tried in order to ascertain the most satisfactory and reliable; his ambition was to attain complete control of the process so that he could always be certain of the result. Porcelain tubes were tried, which he obtained from Wedgwood. They were very liable, however, to allow escape of the gases through pores. Many different methods of obtaining gas-tight stoppers were experimented on, but he does not seem to have found anything really better than the fusible metal. A slight loss of weight in the chalk used seemed inevitable, and the amount of loss varied irregularly; after long trials he ultimately succeeded in reducing this to less than one per cent. Various kinds of carbonate of lime were used, including chalk, limestone, powdered spar, oyster shells, periwinkles, and each of these was crystallised in turn. Many experiments showed that a reaction might take place between the chalk powder and the glass of the tube in which it was contained. The result was a white deposit often crystalline, and a certain amount of uncombined carbonic acid gas which escaped when the tube was opened. No doubt the white mineral was wollastonite. Hall proved that it was a silicate of lime which dissolved in acid and left a cloud of gelatinous silica. Thereafter he used platinum vessels instead of glass to contain the charge of carbonate of lime which he wanted to fuse. The effect of impurities in the material used was also investigated. Critics had urged that his limestone was not pure. Hall aptly replied that this was so much the better; natural limestones were seldom pure, and his point was that limestone might be fused under heat and pressure. He obtained the purest precipitated carbonate of lime, and used also perfectly transparent crystalline spar; the results were, as we might expect, that the pure substances and the fairly coarse

crystalline powder were more difficult to fuse than the very finely ground natural chalk. These results show that Hall had very complete control of his experimental processes, and that even small differences in fusibility did not escape his observation.

As natural limestones are always moist, Hall's attention was next directed to the influence of water on the crystallisation of his powders. This added greatly to the difficulty of the experiments, but by wonderful skill he succeeded in using a few grains of water (apparently up to five per cent. of the weight of the chalk). The result was to improve the crystallisation, for the reason, as Hall believed, that the pressure was increased. He noticed at the same time that hydrogen was produced, which took fire when the gun-barrel was discharged. Probably there was also some carbonic oxide. About this time he was using bars of Russian iron into which a long cylindrical cavity had been bored. He then tried other volatile ingredients such as nitrate of ammona, carbonate of ammonia, and gunpowder. In January 1804 he was able to convert chalk into firm limestone at a temperature about 960° (melting-point of silver) in presence of small quantities of water with a loss of less than one-thousandth part of the chalk used.

Finally he attempted to measure the pressure which was necessary to effect re-crystallisation under the conditions of his experiments. No pressure gauges were available at that date, and after many trials he employed a stopper faced with leather and forced against the mouth of his iron tube by means of weights acting either directly or through a lever. He ultimately succeeded in obtaining gas-tight junctions under pressures ranging from 52 up to 270 atmospheres, and concluded that 52 atmospheres was the least pressure which could be satisfactory. This is equal to the pressure of a column of water 1,700 feet high or to a column of rock 700 feet high. A 'complete marble' was formed at a pressure of 86 atmospheres and carbonate of lime 'absolutely fused' under a pressure of 173 atmospheres.

In reviewing these classic experiments after a lapse of 120 years we feel that there are many points on which we should have liked more detailed information. One essential, for example, is exact chemical analysis of all the materials employed. Even chalk is variable in composition to a by no means negligible extent. Oyster shells and periwinkle shells contain organic matter, which would account for the considerable loss in weight they always exhibited. The use of glass tubes was a defect in the early experiments afterwards remedied by employing platinum vessels. Although in all the experiments the charge was weighed it seems clear that at first at any rate the materials were not carefully dried. In the experiments with water it was seldom possible to provide absolutely against the escape of moisture when the fusible metal was introduced. Most of all we may regret the inadequate means of measuring the temperatures at which the experiments were

conducted. The measurements of pressure were made by the simplest possible means, and it was only by great experimental skill and care that even approximate results could be obtained.

Such criticisms, however, do not mar the magnificent success of Hall's experiments. For nearly a hundred years, in spite of the advance of physical and chemical science, no substantial improvement on his results was attained. His work was immediately recognized as trustworthy and conclusive, and became a classic in the literature of experimental geology. Although not exactly the founder of this school of research, for Spallanzani and De Saussure had made fusion experiments on rocks before his time, he placed the subject in a prominent position among the departments of geological investigation, and did great service in supporting Hutton's theories by evidence of a new and unexpected character.

SOME PROBLEMS IN EVOLUTION

By Professor EDWIN S. GOODRICH, F.R.S.

PRESIDENT OF THE ZOOLOGICAL SECTION

IN all probability factors of inheritance exist, and the fundamental problem of biology is how are the factors of an organism changed, or how does it acquire new factors? In spite of its vast importance, it must be confessed that little advance has been made towards the solution of this problem since the time of Darwin, who considered that variation must ultimately be due to the action of the environment. This conclusion is inevitable, since any closed system will reach a state of equilibrium and continue unchanged, unless affected from without. To say that mutations are due to the mixture or reshuffling of pre-existing factors is merely to push the problem a step farther back, for we must still account for their origin and diversity. The same objection applies to the suggestion that the complex of factors alters by the loss of certain of them. To account for the progressive change in the course of evolution of the factors of inheritance and for the building up of the complex it must be supposed that from time to time new factors have been added; it must further be supposed that new substances have entered into the cycle of metabolism, and have been permanently incorporated as self-propagating ingredients entering into lasting relation with pre-existing factors. We are well aware that living protoplasm contains molecules of large size and extraordinary complexity, and that it may be urged that by their combination in different ways, or by the mere regrouping of the atoms within them, an almost infinite number of changes may result, more than sufficient to account for the mutations which appear. But this does not account for the building up of the original complex. If it must

be admitted that such a building process once occurred, what right have we to suppose that it ceased at a certain period? We are driven, then, to the conclusion that in the course of evolution new material has been swept from the banks into the stream of germ-plasm.

If one may be allowed to speculate still further, may it not be supposed that factors differ in their stability?—that whereas the more stable are merely bent, so to speak, in this or that direction by the environment, and are capable of returning to their original condition, as a gyroscope may return to its former position when pressure is removed, other less stable factors may be permanently distorted, may have their metabolism permanently altered, may take up new substance from the vortex, without at the same time upsetting the system of delicate adjustments whereby the organism keeps alive? In some such way we imagine factorial changes to be brought about and mutations to result.

Let it not be thought for a moment that this admission that factors are alterable opens the door to a Lamarckian interpretation of evolution! According to the Lamarckian doctrine, at all events in its modern form, a character would be inherited after the removal of the stimulus which called it forth in the parent. Now of course, a response once made, a character once formed, may persist for longer or shorter time according as it is stable or not; but that it should continue to be produced when the conditions necessary for its production are no longer present is unthinkable. It may, however, be said that this is to misrepresent the doctrine, and that what is really meant is that the response may so react on and alter the factor as to render it capable of producing the new character under the old conditions. But is this interpretation any more credible than the first?

Let us return to the possible alteration of factors by the environment. Unfortunately there is little evidence as yet on this point. In the course of breeding experiments the occurrence of mutations has repeatedly been observed, but what led to their appearance seems never to have been so clearly established as to satisfy exacting critics. Quite lately, however, Professor M. F. Guyer, of Wisconsin, has brought forward a most interesting case of the apparent alteration at will of a factor or set of factors under definite well-controlled conditions.[7] You will remember that if a tissue substance, blood-serum for instance, of one animal be injected into the circulation of another, this second individual will tend to react by producing an anti-body in its blood to antagonise or neutralise the effect of the foreign serum. Now Professor Guyer's ingenious experiments and results may be briefly summarised as follows. By repeatedly injecting a fowl with the substance of the lens of the eye of a rabbit he obtained anti-lens serum. On injecting this 'sensitised' serum into a pregnant female rabbit it

[7] *American Naturalist*, vol. lv. 1921; *Jour. of Exper. Zoology*, vol. xxxi. 1920.

was found that, while the mother's eyes remained apparently unaffected, some of her offspring developed defective lenses. The defects varied from a slight abnormality to almost complete disappearance. No defects appeared in untreated controls, no defects appeared with non-sensitised sera. On breeding the defective offspring for many generations these defects were found to be inherited, even to tend to increase and to appear more often. When a defective rabbit is crossed with a normal one the defect seems to behave as a Mendelian recessive character, the first generation having normal eyes and the defect reappearing in the second. Further, Professor Guyer claims to have shown that the defect may be inherited through the male as well as the female parent, and is not due to the direct transmission of anti-lens from mother to embryo *in utero*.

If these remarkable results are verified, it is clear that an environmental stimulus, the anti-lens substance, will have been proved to affect not only the development of the lens in the embryo, but also the corresponding factors in the germ-cells of that embryo; and that it causes, by originating some destructive process, a lasting transmissible effect giving rise to a heritable mutation.

Professor Guyer, however, goes farther, and argues that, since a rabbit can also produce anti-lens when injected with lens substance, and since individual animals can even produce anti-bodies when treated with their own tissues, therefore the products of the tissues of an individual may permanently affect the factors carried by its own germ-cells. Moreover he asks, pointing to the well-known stimulative action of internal secretions (hormones and the like), if destructive bodies can be produced, why not constructive bodies also? And so he would have us adopt a sort of modern version of Darwin's theory of Pangenesis, and a Lamarckian view of evolutionary change.

But surely there is a wide difference between such a poisonous or destructive action as he describes and any constructive process. The latter must entail, as I tried to show above, the drawing of new substances into the metabolic vortex. Internal secretions are themselves but characters, products (perhaps of the nature of ferments behaving as environmental conditions, not as self-propagating factors, moulding the responses, but not permanently altering the fundamental structure and composition of the factors of inheritance.

Moreover, the early fossil vertebrates had, in fact, lenses neither larger nor smaller on the average than those of the present day. If destructive anti-lens had been continually produced and had acted, its effect would have been cumulative. A constructive substance must, then, have also been continually produced to counteract it. Such a theory might perhaps be defended; but would it bring us any nearer to the solution of the problem?

The real weakness of the theory is that it does not escape from the fundamental objections we have already put forward as fatal to

Lamarckism. If an effect has been produced, either the supposed constructive substance was present from the first, as an ordinary internal environmental condition necessary for the normal development of the character, or it must have been introduced from without by the application of a new stimulus. The same objection does not apply to the destructive effect. No one doubts that if a factor could be destroyed by a hot needle or picked out with fine forceps the effects of the operation would persist throughout subsequent generations.

Nevertheless, these results are of the greatest interest and importance, and, if corroborated, will mark an epoch in the study of heredity, being apparently the first successful attempt to deal experimentally with a particular factor or set of factors in the germ-plasm.

There remains another question we must try to answer before we close, namely, 'What share has the mind taken in evolution?' From the point of view of the biologist, describing and generalising on what he can observe, evolution may be represented as a series of metabolic changes in living matter moulded by the environment. It will naturally be objected that such a description of life and its manifestations as a physico-chemical mechanism takes no account of mind. Surely, it will be said, mind must have affected the course of evolution, and may indeed be considered as the most important factor in the process. Now, without in the least wishing to deny the importance of the mind, I would maintain that there is no justification for the belief that it has acted or could act as something guiding or interfering with the course of metabolism. This is not the place to enter into a philosophical discussion on the ultimate nature of our experience and its contents, nor would I be competent to do so; nevertheless, a scientific explanation of evolution cannot ignore the problem of mind if it is to satisfy the average man.

Let me put the matter as briefly as possible at the risk of seeming somewhat dogmatic. It will be admitted that all the manifestations of living organisms depend, as mentioned above, on series of physico-chemical changes continuing without break, each step determining that which follows; also that the so-called general laws of physics and of chemistry hold good in living processes. Since, so far as living processes are known and understood, they can be fully explained in accordance with these laws, there is no need and no justification for calling in the help of any special vital force or other directive influence to account for them. Such crude vitalistic theories are now discredited, but tend to return in a more subtle form as the doctrine of the interaction of body and mind, of the influence of the mind on the activities of the body. But, try as we may, we cannot conceive how a physical process can be interrupted or supplemented by non-physical agencies. Rather do we believe that to the continuous physico-chemical series of events there corresponds a continuous series of mental events inevitably connected with it; that the two series are but partial views

or abstractions, two aspects of some more complete whole, the one seen from without, the other from within, the one observed, the other felt. One is capable of being described in scientific language as a consistent series of events in an outside world, the other is ascertained by introspection, and is describable as a series of mental events in psychical terms. There is no possibility of the one affecting or controlling the other, since they are not independent of each other. Indissolubly connected, any change in the one is necessarily accompanied by a corresponding change in the other. The mind is not a product of metabolism as materialism would imply, still less an epiphenomenon or meaningless by-product as some have held. I am well aware that the view just put forward is rejected by many philosophers, nevertheless it seems to me to be the best and indeed the only working hypothesis the biologist can use in the present state of knowledge. The student of biology, however, is not concerned with the building up of systems of philosophy, though he should realise that the mental series of events lies outside the sphere of natural science.

The question, then, which is the more important in evolution, the mental or the physical series, has no meaning, since one cannot happen without the other. The two have evolved together *pari passu*. We know of no mind apart from body, and have no right to assume that metabolic processes can occur without corresponding mental processes, however simple they may be.

Simple response to stimulus is the basis of all behaviour. Responses may be linked together in chains, each acting as a stimulus to start the next; they can be modified by other simultaneous responses, or by the effects left behind by previous responses, and so may be built up into the most complicated behaviour. But owing to our very incomplete knowledge of the physico-chemical events concerned, we constantly, when describing the behaviour of living organisms, pass, so to speak, from the physical to the mental series, filling up the gaps in our knowledge of the one from the other. We thus complete our description of behaviour in terms of mental processes we know only in ourselves (such as feeling, emotion, will) but infer from external evidence to take place in other animals.

In describing a simple reflex action, for instance, the physico-chemical chain of events may appear to be so completely known that the corresponding mental events are usually not mentioned at all, their existence may even be denied. On the contrary, when describing complex behaviour when impulses from external or internal stimuli modify each other before the final result is translated into action, it is the intervening physico-chemical processes which are unknown and perhaps ignored, and the action is said to be voluntary or prompted by emotion or the will.

The point I wish to make, however, is that the actions and behaviour of organisms are responses, are characters in the sense de-

scribed in the earlier part of this address. They are inherited, they vary, they are selected, and evolve like other characters. The distinction so often drawn by psychologists between instinctive behaviour said to be inherited and intelligent behaviour said to be acquired is as misleading and as little justified in this case as in that of structural characters. Time will not allow me to develop this point of view, but I will only mention that instinctive behaviour is carried out by a mechanism developed under the influence of stimuli, chiefly internal, which are constantly present in the normal environmental conditions, while intelligent behaviour depends on responses called forth by stimuli which may or may not be present. Hence, the former is, but the latter may or may not be inherited. As in other cases, the distinction lies in the factors and conditions which produce the results. Instinctive and intelligent behaviour are usually, perhaps always, combined, and one is not more primitive or lower than the other.

It would be a mistake to think that these problems concerning factors and environment, heredity and evolution, are merely matters of academic interest. Knowledge is power, and in the long run it is always the most abstruse researches that yield the most practical results. Already, in the effort to keep up and increase our supply of food, in the constant fight against disease, in education, and in the progress of civilisation generally, we are beginning to appreciate the value of knowledge pursued for its own sake. Could we acquire the power to control and alter at will the factors of inheritance in domesticated animals and plants, and even in man himself, such vast results might be achieved that the past triumphs of the science would fade into insignificance.

Zoology is not merely a descriptive and observational science, it is also an experimental science. For its proper study and the practical training of students and teachers alike, well-equipped modern laboratories are necessary. Moreover, if there is to be a useful and progressive school contributing to the advance of the science, ample means must be given for research in all its branches. Life doubtless arose in the sea, and in the attempt to solve most of the great problems of biology the greatest advances have generally been made by the study of the lower marine organisms. It would be a thousand pities, therefore, if Edinburgh did not avail itself of its fortunate position to offer to the student opportunities for the practical study of marine zoology.

In his autobiography, Darwin complains of the lack of facilities for practical work—the same need is felt at the present time. He would doubtless have been gratified to see the provision made since his day and the excellent use to which it has been put; but what seems adequate to one generation becomes insufficient for the next. We earnestly hope that any appeal that may be made for funds to improve this department of zoology may meet with the generous response it certainly deserves.

APPLIED GEOGRAPHY

By Dr. D. G. HOGARTH, C.M.G.

PRESIDENT OF THE GEOGRAPHICAL SECTION

THE term which I have taken for the title of my address has been in use for some years as a general designation of lendings or borrowings of geographical results, whether by a geographer who applies the material of his own science to another, or by a geologist or a meteorologist, or again an ethnologist or historian, who borrows of the geographer. Whether geography makes the loan of her own motion or not, the interest in view, as it seems to me, is primarily that, not of geography, but of another science or study. The open question whether that interest will be served better if the actual application be made by the geographer or by the other scientist or student does not concern us now.

Such applications are of the highest interest and value as studies, and, still more, as means of education. As studies, not merely are they links between sciences, but they tend to become new subjects of research, and to develop with time into independent sciences. As means of education they are used more generally, and prove themselves of higher potency than the pure sciences from which or to which, respectively, the loans are effected. But, in my view, geography, thus applied, passes, in the process of application, into a foreign province and under another control. It is most proper, as well as most profitable, for a geographer to work in that foreign field; but, while he stays in it, he is, in military parlance, seconded.

Logical as this view may appear, and often as, in fact, it has been stated or implied by others (for example, by one at least of my predecessors in this chair, Sir Charles Close, who delivered his presidential address to the section at the Portsmouth Meeting in 1911), it does not square with some conceptions of geography put forward by high authorities of recent years. These represent differently the status of some of the studies, into which, as I maintain, geography enters as a subordinate and secondary element. In particular, there is a school, represented in this country and more strongly in America, which claims for geography what, in my view, is an historical or ethnological or even psychological study, using geographical data towards the solution of problems in its own field; and some even consider this not merely a function of true geography, but its principal function now and for the future. Their 'new geography' is and is to be the study of 'human response to land-forms.' This is an extreme American statement; but the same idea is instinct in such utterances, more sober and guarded, as that of a great geographer, Dr. H. R. Mill, to the effect that the

ultimate problem of geography is 'the demonstrative and quantitative proof of the control exercised by the Earth's crust on the mental processes of its inhabitants. Dr. Mill is too profound a man of science not to guard himself, by that saving word 'ultimate,' from such retorts as Professor Ellsworth Huntington, of Yale, has offered to the extreme American statement. If, the latter argued, geography is actually the study of the human response to land-forms, then, as a science it is in its infancy, or, rather, it has returned to a second childhood; for it has hardly begun to collect exact data to this particular end, or to treat them statistically, or to apply to them the methods of isolation that exact science demands. In this country geographers are less inclined to interpret 'new geography' on such revolutionary lines; but one suspects a tendency towards the American view in both their principles and their practice—in their choice of lines of inquiry or research and their choice of subjects for education. The concentration on man, which characterizes geographical teaching in the University of London, and the almost exclusive attention paid to Economic Geography in the geographical curricula of some other British Universities make in that direction. In educational practice, this bias does good, rather than harm, if the geographer bears in mind that Geography proper has only one function to perform in regard to man—namely, to investigate, account for, and state his distribution over terrestrial space—and that this function cannot be performed to any good purpose except upon a basis of Physical Geography—that is, on knowledge of the disposition and relation of the Earth's physical features, so far as ascertained to date. To deal with the effect of man's distribution on his mental processes or political and economic action is to deal with him geographically indeed, but by applications of geography to psychology, to history, to sociology, to ethnology, to economics, for the ends of these sciences; though the interests of geography may be, and often are, well served in the process by reflection of light on its own problems of distribution. If in instruction, as distinct from research, the geographer, realising that, when he introduces these subjects to his pupils, he will be teaching them not geography, but another science with the help of geography, insists on their having been grounded previously or elsewhere in what he is to apply—namely, the facts of physical distribution—all will be well. The application will be a sound step forward in education, more potent perhaps for training general intelligence than the teaching of pure geography at the earlier stage, because making a wider and more compelling appeal to imaginative interest and pointing the adolescent mind to a more complicated field of thought. But if geography is applied to instruction in other sciences without the recipients having learned what it is in itself, then all will be wrong. The teacher will talk a language not under-

stood, and the value of what he is applying cannot be appreciated by the pupils.

If I leave this argument there for the moment, it is with the intention of returning to it before I end today. It goes to the root, as it seems to me, of the unsatisfactory nature of much geographical insruction given at present in our islands. The actual policy of the English Board of Education seems to contemplate that geography should be taught to secondary students, only in connection with history. If this policy were realised in instructional practice by encouragement or compulsion of secondary students to undergo courses of geography proper, with a view to promotion subsequently to classes in historical geography (*i. e.*, if history be treated geographically by application of another science previously studied), it would be sound. But I gather from Sir Halford Mackinder's recent report that such is not the practice. Courses in geography proper are not encouraged during the secondary period of education at all. Encouragement ceases with the primary period, at an age before which only the most elementary instruction in such a science can be assimilated—when, indeed, not much more can be expected of pupils than the memorising of those summary diagrammatic expressions of geographical results, which are maps. How these results have been arrived at, what sort of causes account for physical distribution, how multifarious are its facts and features which maps cannot express even on the minutest scale—these things must be instilled into minds more robust than those of children under fourteen; and until some adequate idea of them has been imbibed it is little use to teach history geographically. So, at least, this matter seems to me.

It will be patent enough by now that I am maintaining geography proper to be the study of the spatial distribution of all physical features on the surface of this earth. My view is, of course, neither novel nor rare. Almost all who of late years have discussed the scope of geography have agreed that distribution is of its essence. Among the most recent exponents of that view have been two directors of the Oxford School, Sir Halford Mackinder and Professor Herbertson. When, however, I add that the study of distribution, rightly understood, is the whole essential function of geography, I part company from the theory of some of my predecessors and contemporaries, and the practice of more. But our divergence will be found to be not serious; for not only do I mean a great deal by the study of distribution—quite enough for the function of any one science!—but I claim for geography to the exclusion of any other science all study of spatial distribution on the earth's surface. This study has been its well recognised function ever since a science of that name has come to be restricted to the features of the terrestrial surface—that is, ever since 'geography' in the eighteenth century had to abandon to its child geo-

logy the study of what lies below that surface even as earlier it had abandoned the study of the firmament to an elder child, astronomy. Though geography has borne other children since, who have grown to independent scientific life, none of these has robbed her of that one immemorial function. On the contrary, they call upon her to exercise it still on their behalf.

Let no one suppose that I mean by this study and this function merely what Professor Herbertson so indignantly repudiated for an adequate content of his science—physiography *plus* descriptive topography. Geography includes these things, of course, but she embraces also all investigation both of the actual distribution of the earth's superficial features and of the causes of the distribution, the last a profound and intricate subject towards the solution of which she has to summon assistance from many other sciences and studies. She includes, further, in her field, for the accurate statement of actual distribution, all the processes of survey—a highly specialised function to the due performance of which other sciences again lend indispensable aid; and, also, for the diagrammatic presentation of synthetised results for practical use, the equally highly specialised processes of cartography. That seems to me an ample field, with more than sufficient variety of expert functions, for any one science. And I have not taken into account either the part geography has to play in aiding other sciences, as they aid her, by application of her data, or, again, certain investigations of terrestrial phenomena, at present incumbent upon her, because special sciences to deal with them have not yet been developed—or, at least, fully developed—although their ultimate growth to independence can be foreseen or has already gone far. Such, for the moment, are geodetic investigations, in this country at any rate. In Germany, I understand, geodesy has attained already the status of a distinct specialism. Here the child has hardly separate existence. But beyond a doubt it will part from its parent, even as oceanography has parted. Indeed some day, in a future far too distant to be foreseen now, many, or most, of the investigations which now occupy the chief attention of geographical researchers may cease to be necessary. A time must come when the actual distribution of all phenomena on the earth's surface will have been ascertained, and all the relief upon it and every superficial feature which cartography can possibly express in its diagrammatic way will have been set out finally on the map. That moment, however, will not be the end of geography as a science, for there will still remain the investigation of the causes of distribution, the scientific statement of its facts, and the application of these to other sciences. Let us not, however, worry about any ultimate restriction of the functions of our science. The discovery and correlation of all the facts of geographical distribution and their final presentation in diagram-

matic form are not much more imminent than the exhaustion of the material of any other science!

In the meantime, for a wholly indeterminate interval, let us see to it that all means of investigating the phenomena of spatial distribution on the earth be promoted, without discouragement of this or that tentative means as unscientific. The exploration of the terrestrial surface should be appreciated as a process of many necessary stages graduated from ignorance up to perfect knowledge. It is to the credit of the Royal Geographical Society that it has always encouraged tentative, and, if you like, unscientific first efforts of exploration, especially in parts of the world where, if every prospect pleases, man is very vile. Unscientific explorations are often the only possible means to the beginning of knowledge. Where an ordinary compass cannot be used except at instant risk of death it is worth while to push in a succession of explorers unequipped with any scientific knowledge or apparatus at all, not merely to gain what few geographical data untrained eyes may see and uneducated memories retain, but to open a road on which ultimately a scientific explorer may hope to pass and work, because the local population has grown, by intercourse with his unscientific precursors, less hostile and more indifferent to his prying activities. There seems to me now and then to be too much criticism of Columbus. If he thought America was India he had none the less found America.

I have claimed for the geographer's proper field the study of the causation of distribution. I am aware that this claim has been, and is denied to geography by some students of the sciences which he necessarily calls to his help. But if a science is to be denied access to the fields of other sciences except it take service under them, what science shall be saved? I admit, however, that some disputes can hardly be avoided, where respective boundaries are not yet well delimited. Better delimitation is called for in the interest of geography, because lack of definition, causing doubts and questions about her scope, confuses the distinction between the science and its application. The doubts are not really symptoms of anything wrong with geography, but, since they may suggest to the popular mind that in fact something is wrong, they can be causes of disease. Their constant genesis is to be found in the history of a science, whose scope has not always been the same, but has contracted during the course of ages in certain directions while expanding in others. If, in the third century B. C., Eratosthenes had been asked what he meant by geography, he would have replied, the science of all the physical environment of man whether above, upon, or below the surface of the earth, as well as of man himself as a physical entity. He would have claimed for its field what lies between the farthest star and the heart of our globe, and the nature and relation of everything composing the universe. Geography, in fact, was then not only the whole of natural science, as we understand the term, but also

everything to which another term, ethnology, might now be stretched at its very widest.

Look forward now across two thousand years to the end of the eighteenth century A. D. Geography has long become a mother. She has conceived and borne astronomy, chemistry, botany, zoology, and many more children, of whom about the youngest is geology. They have all existences separate from her and stand on their own feet, but they preserve a filial connection with her and depend still on their mother science for a certain common service, while taking off her hands other services she once performed. Restricting the scope of her activities, they have set her free to develop new ones. In doing this she will conceive again and again and bear yet other children during the century to follow—meteorology, climatology, oceanography, ethnology, anthropology and more. Again, and still more narrowly, this new brood will limit the mother's scope; but ever and ever fecund, she will find fresh activities in the vast field of earth knowledge, and once and again conceive anew. The latest child that she has borne and seen stand erect is, as I have said, geodesy; and she has not done with conceiving.

Ever losing sections of her original field and functions, ever adding new sections to them, geography can hardly help suggesting doubts to others and even to herself. There must always be a certain indefiniteness about a field on whose edges fresh specialisms are for ever developing toward a point at which they will break away to grow alone into new sciences. The mother holds on awhile to the child, sharing its activities, loth to let go, perhaps even a little jealous of its growing independence. It has not been easy to say at any given moment where geography's functions have ended and those of, say, geology or ethnology have begun. Moreover, it is inevitably asked about this fissiparous science from which function after function has detached itself to lead life apart—what, if the process continues, as it shows every sign of doing, will be left to geography later or sooner? Will it not be split up among divers specialisms, and become in time a venerable memory? It is a natural, perhaps a necessary, question. But what is wholly unnecessary is that any answer should be returned which implies a doubt that geography has a field of research and study essentially hers yesterday, to-day, and to-morrow; still less which implies any suspicion that because of her constant parturition of specialisms geography is, or is likely in any future that can be foreseen, to be moribund.

SCIENTIFIC IDEALISM[1]

By Dr. WILLIAM E. RITTER

SCRIPPS INSTITUTE, LA JOLLA, CALIFORNIA

IDEALISM is dead—at least many people think so. And no small number of those who think thus are persons of humane sentiments withal, and hold their belief under compulsion rather than willingly. They believe the evidence compels them to accept this view, whether it be agreeable to them or not. How else, they reason, can the course of events of these later decades be interpreted?

The history of man is the story of the terribly brutal reality of his existence on earth and his efforts to escape from this reality into some ideal realm wherein the peace and happiness and joy occasionally experienced in life shall be perfected and endure forever.

So powerful has been the allurement of this ideal realm that many of our race in ages past have devoted their best power, sometimes even their very lives to exploiting it and devising ways and means by which all may finally reach this promised land. These rare ones are acclaimed great among men and accepted as teachers and leaders just because they express the common longings of mankind, of the lowly as well as of the great.

In all the ages and culture stages of the past imaginarily perfect conditions of life have been among the most compelling motives with humanity. These imaginings have been near the heart of all the great religions and all the great philosophies of the world, their culmination as philosophy having been, probably, the several forms of idealism of the eighteenth and early nineteenth centuries. But what has come of it all?

If the realism of these questioners is of the dramatic sort, the answer they give to their own question is likely to be brief and laconic. A few dozen words and a gesture will tell the story: Germany and Austro-Hungary in August, 1914, and again in October, 1918! Russia in August, 1914, in April, 1917, in November, 1918, and today! Treaty making in Versailles in 1919! The human misery of all Europe during the war years and up to the present moment! The astounding transformations that have occurred in the hearts and lives of our own people since the new era opened! Finally, the uncertainty, the fore-

[1] President's address at the Berkeley Meeting of the Pacific Division, American Association for the Advancement of Science, August 4-7, 1921.

boding, the background of distrust, hatred, and fear with which all the peoples of the earth look toward the future!

Surely there is ground enough for the supposition that realism, a realism as stupid and brutal as Satan himself could rejoice in, has at last established its full claims—that idealism has departed from the earth wholly and for all time.

And what, they ask, has contributed more to these results than science? Have not scientific discovery and invention based on such discovery so involved man in a network of material forces and mechanical devices that he can hardly satisfy a single need, gratify a single desire, form a single idea, or think a single thought without the permission of this tyranny of material things?

For a modern seriously to attempt to live traditional idealism for one day could result only in death or something worse before the setting of the sun.

Nor is this the worst that science has done. In these grosser matters the injury to idealism has consisted only in thrusting the sensible realities of nature more numerously, more variedly and more insistently than ever before into the problem of living from hour to hour and day to day.

Of graver concern, science has, we are told to remember, entered the very domain of philosophy and besieged the citadel of idealism itself. Even the strongholds of morality and religion are not spared by the advance of realistic science. Copernican astronomy, Lavoisian chemistry, Lyellian geology and Darwinian biology have united in constructing so solid a foundation for a realistic philosophy of all life that the time-honored super-structure of idealistic philosophy is doomed to collapse and ruin.

The fact is thrown into our faces by the acceptors of the view that science is implacably hostile to idealism, that in these last years, not satisfied with its imminent victory over theoretic idealism, it has entered into full alliance with the ancient powers of darkness and malignity to accomplish the destruction of idealism itself and of all that idealism has created in the world.

High power explosives with guns and tanks and dreadnaughts and submarines and aircraft to make them effective went far toward realizing this ambition, but the finishing stroke is poison gases. The abundance of raw material for their manufacture, the ease of their transportation, the secrecy with which their nature and manufacture can be surrounded and, finally, the large co-efficient of deadliness of the best of them, make them very promising as means for completing the business of destroying all the works of civilized races, if not the races themselves. Of course no people, not even the scientists whose

devotion to research discovers the gases, intended to use these upon *themselves*. The enemy alone are to be destroyed. But since the enemy can, if also scientifically civilized, discover poison gases too, the result, whether consciously aimed at or not—the destruction of all idealism and its fruits—is certain.

But is this picture of the state of things really true? Is science indeed so destructive an enemy to idealism?

I deny it. Never, I affirm, has science been purposely hostile to idealism. Never has it designed to act against idealism. In so far as science has injured idealism it has done so undesignedly and unwittingly. Science has gone on its way, single-minded, bent only on ever increasing man's store of natural knowledge, on penetrating ever farther into the depths of natural truth.

But denial that the harm done by science to idealism has been intentional is of little consequence. What I chiefly care about is not the blamelessness of science for its injury to idealism. I would set forth the true relation of science to idealism and the moral obligation which this relation forces upon science. My aim is to acknowledge the terrible error committed by science in holding, even by implication, that it knows nothing about morals and has no moral obligations, and to show something of the nature of its obligation.

Speaking in broad terms, what I want to point out is that once science gives serious attention to the question of its own relation to idealism and realism it recognizes that the first question to be decided is not that of idealism vs. realism, not that of idealism or no idealism, nor of realism or no realism. Rather it is the question of what in essence idealism is, and what realism is.

To push this inquiry to exhaustiveness would need days. We seem stopped on the threshold by the demand for a treatise while all we can have is a tract. But it is not wholly so. From its very office as a ministrant to the common life of mankind, science can, if true to herself, concentrate her elaborate, forbidding treatises into simple, dramatic, appealing tracts at the urgent need of humanity.

It is in response to the danger call of civilization that I seek to reduce to the dimensions of a tract, the laborious findings of science on the real nature of the conflict between humanity's longings, beliefs, hopes and faiths and those forces—grim, powerful and ever alert—which oppose their attainment.

Notice, in the first place, the kinship of science with our ordinary intelligence. Nobody doubts that every item of our matter-of-fact knowledge about the universe in which we live is anything else than part and parcel of our general store of knowledge. Surely what the housewife knows about the things of her home; what

the workman knows about his tools and materials; what the merchant knows about his goods; what the engineer knows about the structure, the plans and the materials of which it is made; what the physician knows about our bodily members in health and disease, are but parts of common knowledge. But the articles that so much concern the housewife, the workman, the merchant, the engineer, the physician are the very same that concern the scientist. The only difference is that they concern the housewife, workman, engineer and physician more immediately, more vitally than they do the scientist. So the scientist, being perforce also domestic, workman, merchant and so on, is less apt to contend that his special knowledge is wholy different in kind from the knowledge of work-a-day men and women. None have cherished the characterization of science as organized common sense more than have scientists.

But again, has anybody ever doubted that mental structures in the form of memories, guesses, views and ideas enter essentially and largely into the intelligent pursuit of all callings? Planning the next meal, the next house-cleaning, the next jacket for baby; visualizing more effective wrenches and augurs and knives; imagining hats and shoes and gowns more appealing to customers, are part of the very life of the successful housekeeper, mechanic, merchant. Just so it is as to essential mental procedure with the scientific investigator. Apart from something mentally pictured but not yet realized—apart from some hypothesis—scientific discovery is unthinkable. Would any scientist claim that science is less dependent on ideas than is housekeeping, blacksmithing or merchandizing?

But having ideas is never the whole story in any department of rational human living. Everywhere and always the mental picture, the idea is something aimed at, something needed or desired for the fulfilment or completion or rounding out of some still larger, more inclusive need or desire. Whether the adage "Nothing existeth to itself alone" be strictly true or not, it certainly is true as to ideas. It is as much the nature of ideas to be in relation with one another and with other things as it is for them to exist at all. It is from this inter-relatedness, this mutual dependence of ideas and their relation to the individual's life as a whole that they get whatever drive and potency they have. But ideas plus the valuations placed upon them and the impulsions to act connected with them are exactly the things to which common experience has given the name ideals. Ideals are ideas in action or ready for action toward some supposedly good end.

From this it is seen that the scientist, especially the investigator, is of necessity an idealist by the same token by which the ordinary individual is an idealist. His idealism differs from that of other men only

as his technical knowledge differs from their common knowledge; namely, in that he uses his technical knowledge differently from the way practical men use their common knowledge. The outcome of this is the perception that science is not only idealistic but that its idealism marks the very summit of true, that is natural, idealism.

The idealism of Christian theology and last century's speculative philosophy are pseudo-idealism. They are disembodied idealism. They are mythical or dramaturgic idealism. If consequently, they have been stripped of some of their power it is only false power that has been taken from them and they have suffered only as thousands upon thousands of other products of man's imagination have suffered when it breaks away from its naturalistic setting and its control by the totality of human life.

If science is so beneficent in aim, how comes it that in spite of its gigantic prevalence in our day, that day fraught though it be with calamity and human misery perhaps as terrible as any of all the ages past, is yet heavy with borebodings of still greater calamity? Manifestly something has stood in the way, is standing in the way of man's becoming the beneficiary of this, surely one of the most notable and unique of all his creations.

Is it possible that man should bring into existence so mighty a thing, so potentially beneficent a thing as science and yet fail to reap its benefits; indeed, should allow it to become a powerful ally of forces working to his ruin?

Astounding though the truth may be, an open-minded reading of the story of man's career on earth reveals that he has *always been doing just that sort of thing!* Human history furnishes no guarantee that man will use any good thing, even of his own creating, to his own full and lasting benefit.

In all the stages of human culture from the lowest savagery to the highest civilization men demonstrate their ability to employ their highest spiritual powers as well as their lowest physical powers to their own harm, even to their destruction. Religion, art, learning, philanthropy no less than appetite, sex and material wealth—man has time and again made to contribute to his own undoing. This is a truth the perception of which is greatly important. But of still greater importance is the perception of another closely related truth, namely that with civilized man it lies ever within the range of his intelligence to choose that course of action which will make him a continuous beneficiary of anything his intelligence enables him to produce. In its very nature intelligence is able to prevent its own creations from being harmful. Of course man will never choose that which he is certain will do him more harm than good. It is only as to probabilities of harm and good, or greater and lesser good, or greater and lesser harm, that his choosing so often goes amiss.

To gain an understanding of these wonderful paradoxes of human nature would require a treatise. Sufficient to say that it is possible to go far toward such an understanding if we start with a mind wide open to the idea of man's kindred with the rest of living nature, particularly with the rest of animal nature, and go through to the end vigorously and unflinchingly. For myself, I am convinced that western civilization has come at last to a situation where nothing short of an unqualifiedly and carefully worked out *system of natural ethics will secure its continued progress; indeed, will save it from deterioration and final decay.*

Ours is a day for great and fateful decisions. Mighty goals of objective reality and mighty possibilities of action must be chosen among. Neither optimism nor pessimism but that confidence which the wisely informed can alone possess is now, as never before, the way of salvation.

Let me outline what seems to me the most important part scientists must play in developing such an ethics as has just been mentioned and making the vital choices presented by the situation. The first thing for them to do is to accept unfalteringly and insist upon the necessity that all others shall accept, the *facts*, all of them, without addition or subtraction, which the system of nature, including human nature presents. The haggling that has gone on among the learned of the western world for two thousand years over the question of whether nature revealed through our senses is the ultimate reality or an illusion of one sort or another, must be and I believe is in a fair way to be brought to an end before long. Nevertheless it is astonishing, once one's attention is fixed on the point, how prevalent still even among men of science is the ancient state of uncertainty about the value of facts, and the still more ancient custom of furbishing them up in hundreds of ways to suit preadopted ideas and ideals. Many an excellent scientist still speaks of the laws of nature as though they were quite apart from and above the facts of nature. To such scientists laws are the essence of truth while facts are without much dignity, being mere objects of sense. Beyond a few such vital facts as the body's need for air, water and solid food, it seems that many scientists, in common with millions of the unscientific, still conceive themselves privileged to select such facts as interest them and to ignore all such as do not interest them. Uncritical a priorism still flourishes mightily in one form or another in the home of science. These marks of immaturity of science produce, under the stress of modern conditions, sundry untoward consequences. For one thing a new kind of criticism of science has been growing up in very recent years. The old conflict which theology forced upon science during the early centuries of the intellectual rejuvenation of Europe virtually ended about fifty years ago with science triumphant.

This new criticism which science is encountering is sociological and ethical rather than theological. The essense of the criticism is that science is not regardful of, indeed is largely inimical to, the spiritual welfare of man. This results, it is charged, from the avowed materialistic and mechanistic character of science. For one I frankly admit that there is much justice in this criticism, but I believe close scrutiny of the situation will discern that the real grounds of it are less in the fact that science is materialistic and mechanistic than that it *belittles what is greatest and best in human nature, especially in human personality.*

What is the defect within the body of science that makes it open to such criticism?

For several decades past there has been great controversy within the domain of the biological sciences over the relative merit of mechanism and vitalism. This controversy is largely academic, and consequently shows no signs of reaching a conclusion. The solution will come, I am quite sure, through the emergence of the problem from the realm of pure theory into that of practical life. The form which the inquiry assumes when it comes into the realm of human actuality is this: Accepting the patent fact that man is so wonderfully machine-like that he may be called a machine, at least provisionally, the question arises in what sense a machine? Would he be a machine in the sense of mathematical mechanics or in some other sense? The theory that he is a machine after the manner of mathematical mechanics disposes of itself quickly and completely the moment it submits to the test of practicability. Nothing is more distinctive of manufactured machines than that they can be standardized. All the individual machines of a particular kind can be so constructed that all the parts are interchangeable. Wheel for wheel, shaft for shaft, lever for lever, plate for plate, bolt for bolt—they are cast, often literally, in the same mold. To the last detail it matters not at all which piece goes into which machine. And note what is implied in the expression the "assembling" of manufactured machines—*pre*design and independent fabrication are implied.

These marks set off the manufactured machine so sharply from the human machine, if we decide it may so be called, that no one, not even the most dogmatic bio-mechanist, would deny the facts. Several other equally important differences could be pointed out, but may be omitted for brevity's sake. If men, actual men, are to be called machines, the term must have a sharply different meaning from what it has to the manufacturer. What shall this different meaning be? How shall it be arrived at?

Nothing stands out more unequivocally in the natural history of the human species, particularly of those portions of it that have made notable advances in culture, than that such advances have been due pri-

marily to a very few individuals who are called great because of their special capacities. The fact is never denied. All progress is initiated by the great warrior, the great political organizer, the great poet, the great philosopher, the great explorer, the great inventor, the great physician, the great teacher—one or a very few of each kind for each nation. Except for these rare ones there would be little or no cultural progress, little or no civilization. The fact, I say, is not in question. Even when due allowance is made for the pressure, external and internal, of general need, the importance and rôle of which I do not for a moment minimize, that pressure seems sure to come largely to naught unless the exceptional individual arises to lead and guide the latent forces. Only when it comes to interpreting the facts is there question. Of course one who is committed to the dogma that natural law in the sense of unvarying regularity, of perfect evenness of procedure, is the essence of natural truth, while facts are only sensory, is bound to find some way to avoid accepting these great *personalities* as truly significant so far as the general scheme of things is concerned. They must be reduced to "nothing buts" somehow, when a universal view is sought. They are to be regarded as accidents or by-products in the operation of central forces or of environmental pressure according to the last decade's biological orthodoxy. Or according to this decade's biological orthodoxy they are mere somatic variants, wholly independent of the germ plasm and consequently meaningless so far as the real part of organic matter is concerned. It is admitted that such exceptional personalities have cut some figure in the past career of man. For the future, with the improvement of the germ plasm under eugenic guidance, their role will become less and less until finally there will be reached the far-off state of absolute uniformity in an excellence which formerly would have been called divine.

The logically ideal human goal of the mechanistic philosophy is that all men shall be standardized after the manner of automobiles, on a model that is eugenically perfect. Man, germinally perfected, according to this philosophy would be standardized on the level, say of Packard limousines. Fords, Chevrolets, Essexes—small, cheap, and worst of all, different, would be eliminated.

Pray do not miss the main point here. You can hardly fail to see that it concerns the moral bearings of the mechanistic philosophy. But particular moral qualities and criteria of right and wrong are not my present subject. My point is rather to show that the dead-levelness of that philosophy has no room for such conception as right and wrong at all. The basal question is: Could there be such a thing as virtue if there were nothing but virtue, or if virtue were one only and that one wholly devoid of gradation? The mechanistic philosophy of life implies a solution of the problem of good and evil by eliminating difference.

This brings me to the place were I can indicate the direction in which the solution lies of biology's controversey over mechanism and vitalism. The cue is given by the demand of nature herself that personality shall be accepted and respected. Common sense surely finds no difficulty in heeding this demand, nor can it object to calling man a machine if some way of designating the machine shall be adopted which recognizes the obvious difference between the human and any inanimate machine whatsoever. And no designation, thus discriminative, could be more satisfactory than the simple word "living" prefixed to the word machine when the human or any other kind of animal is referred to. If the difference between a living man and the same man dead be accepted at face value, I am quite sure all sensible persons would willingly recognize men as machines—would even be willing to be called machines themselves.

The practical objection to the mechanical philosophy of life is that because it has no place in its scheme for the person it really has no place for life itself. A non-living thing is more real and hence more significant than a living one to this philosophy. A dead horse would be as valuable as a live one to the mechanistic philosopher who should stick to his philosophy in his practical life.

For brevity's sake I am going to assume that in any imaginable real world of real men, women and children, difference both in kind and degree is as indispensable to virtue as is food or anything else without which life could not exist. And here our reflections reach far beyond the mechanical philosophy, for we cut square across the main axis of ethical theory that has dominated European thought for many centuries, that theory hinging on belief in the ultimate good, necessarily one and alone because without a rival, as the proper goal of human striving.

There is now general agreement, I believe, among those who work practically as contrasted with those who discourse abstractedly on moral problems, that one cannot rightly assess or wisely promote a particular good until he knows what evil lurks within or behind it. Nor can he effectively combat a particular evil until he knows what good is mingled with it. These things I assume without argument, for I must leave a little time in which to show how diversity of talent and virtue, even to the greatest genius, though irreconcilable with a rigorously mechanistic philosophy of human life, is perfectly reconcilable with a naturalistic philosophy conceived in accordance with the best traditions of the natural history sciences.

Let me be very objective. Systematic botany and zoology have long been the type of natural history or the natural sciences. In common practice they have been placed over against the physical sciences on the one hand and the humanistic sciences on the other. Fixing attention more on subject matter than on knowledge corresponding to it, we see at once that nothing sets the plant and animal worlds off from the

inanimate world more obtrusively than the enormous number and diversity of kinds in the former as contrasted with those in the latter. Then comparing the plant and animal world with the human world we see that nothing stands out more sharply than the diversity of individuals in the human world as contrasted with that in the plant and animal worlds. The point is brought home with great force by noticing that each individual in the human world has a name all to itself whereas very little of this occurs in either of the other worlds. But the exceptions are highly significant. A few of the higher animals, notably those most closely associated with man, do have names. Speaking broadly, the human world presents itself to our understanding as composed of *individuals* and the plant and animal worlds as composed of *species*, while the inanimate world, sharply contrasted with both, stands in our knowledge as composed of a comparatively few kinds of *mass* and *energy*. The continents of the earth appear as land masses and the seas as bodies of water. Cloud masses bring rain, and coal and oil deposits and mountain streams furnish power. The point to be kept in the foreground is the indubitable fact that all solid advance in science has done as much to validate *diversity* in nature as it has to validate *uniformity*. It may be said with strict truthfulness, I think, that science rests just as much on laws of diversity as it does on laws of uniformity. There is no justification, psychological, logical or of any other sort for the common assumption that the essence of scientific knowledge is uniformity alone. Surely we cannot affirm that there could be scientific or any other knowledge without uniformity in nature. But equally surely, we cannot affirm that there could be scientific or any other knowledge without diversity in nature.

Of the many chapters in the history of science that could be drawn upon for proof of the conclusions just stated time will permit the notice of but one. But that one is epochal and crucial.

I refer to the fact that variety—difference—in living nature had to be *taken*, as though a thing of free grace, by Darwin for the very foundation of his theory of descent. And I call attention to this vital truth: Darwin and all the ablest naturalists since his time have devoted some of their best powers of observation and of thought to the problem of organic variety and variation, the one unqualifiedly positive result of which has been to widen and deepen the recognized fact of such diversity. Almost endless has been the controversy over the *casual explanation* of variation; but over the *fact of it*, no controversy at all. So it happens that when the naturalist passes from the world of plants and of animals to that of man, preserving the mental attitude and using the general method which his whole career has made second nature to him, he finds the individuality and personality so distinctive of the new realm readily conformable to his disciplinary predilection, his mental and manual technique, and his conceptual scheme.

One fact, however, though by no means new to him, stands out with such boldness in the new realm as to make him ply his methods of treating diversity with more assiduity and thoughtfulness than ever before. That fact is this very one of personality. The material with which he deals in the human realm compels him to notice attentively that the separateness and independence of human beings are not only quantitative and numerical but are qualitative as well. They are not only isolated and thus individual but they are differently individual. Every human being is not merely an *other*, relative to all the rest, but it is a *different* other.

I call special attention to the fact that *otherness* and *qualitatively different otherness* are very distinct conceptions, and I insist on the importance of the distinction, so vitally does it concern practical human affairs. Recognition of this distinction would be promoted by adopting distinctive terms for the two. There should be a general term for mere numerical otherness and another term for qualitatively different otherness. In my own usage I have come to make the two terms *individuality* and *personality* serve these ends. Latterly for me an individual man, woman, child, is only an *other* man, woman, child; while a personal man, woman, or child is not only an *other* but a different other. The full significance of thus distinguishing individuality from personality is seen only when we consider it as pertaining to the social and ethical realms.

In order rightly to exhibit it in these realms it is necessary to refer to still another aspect of the evolution theory, that is the adaptive character of living things. That man is dependent upon adaptation to his environment, as are all other organisms, is now so much a truism that the general fact only needs referring to as a preliminary to mentioning an aspect of the broad problem which has not yet got a sufficiently secure and influential place either in common knowledge or science. That men, like all other organisms must be adapted to their surroundings is so obvious that no one questions it. But recognizing that adaptation is essential in *certain aspects* of life and in the relation of life to certain aspects of environment, is quite a different thing from recognizing that *every aspect* of life whatever, is adaptive to environment, environment being considered broadly enough.

Beginning in modern times with the astronomy of Copernicus and Galileo the whole march of physical science onward to this very day with its discoveries like those of the Curies and Michelson, have been toward a commanding outlook from which may be seen the unity of all inanimate nature. Similarly the march of biological science has been toward a commanding outlook from which the unity of living nature is in clear sight. All this has brought it to pass that an adequate interpretation of man's relation to nature cannot be reached by

taking man and environment each piece-meal, with many of the pieces quite ignored even at that.

Nothing less than human nature in its entirety will suffice for the basis of modern interpretation of man's relation to nature. Consequently when that relation is expressed in the terms of adaptation and environment each must be generalized. Every aspect of human life, spiritual as well as physical, must be recognized as adaptively related to some of the aspects of the system of nature as a whole in its role as environment of human life. Not positive kowledge alone, but art, fine as well as industrial, philosophy, and religion, are manifestations of man's effort to solve the problem of his existence upon earth. They are all partly means and partly ends in the struggle for existence, this familiar and much abused phrase being rightly understood.

And now for the main point in connection with the idea of adaptation. I have just referred to the abused phrase "struggle for existence." One aspect of the abuse of it is in applying it everywhere and at all times but without any analytical definition of it. It is constantly used with its most general meaning but rarely so applied to any special instance. Yet a little reflection brings to light the glaring inadequacy of such usage. Does any one suppose that the struggle of a tree for existence is the same kind of struggle as that of a fish or a bird or a man? Is anything more obvious than that what a sea anemone does in struggling for existence is quite different from what a lion does? All manner of sophistical argument can, I am aware, be produced to justify common practice in this matter. But the facts of the situation are so obvious that for the unsophisticated these arguments do not need reviewing or answering. Manifestly the principle according to which the idea of struggle in living nature must be applied if it is to correspond to the facts and to be really useful, must be expressed about as follows: *The general phrase, struggle for existence, is meaningless for any particular plant or animal except as the struggle is for the existence of that plant or animal, according to its particular kind.*

A tree struggles for a tree's existence not for a fish's or a bird's or a man's existence; and furthermore in each case for some particular kind of tree or fish or man. An oak's struggle is different from a pine's struggle; a Fijian's struggle is different from a Parisian's, and so on through the whole gamut of life, past, present and future.

Let us bring this principle home with all its inherent force. To this end we fix attention upon that portion of the animal realm to which we ourselves belong; namely the portion equipped with highly developed muscular and nervous systems and body members for making these systems effective. Nothing is more obvious even to commonsense zoology than that the part of animal creation thus equipped falls naturally into two main divisions. There are brute animals and there are

human animals. And what differences between brutes and humans are the most striking? There are at least two which stand out so conspicuously that even a child notices them. These are first, the upright posture of the human being, by which his hands are freed from the locomotor function and made available for all sorts of activities in obedience to intelligence; and second, the language mode of expression of the human animal. To be sure, neither of these separates the human from the brute absolutely. If they did they would be quite out of harmony with the principles which prevail everywhere in natural history and so would be far less significant. Many brute animals do assume the upright posture to some degree and use their fore limbs for other purposes than moving about; and many of them surely express themselves to some extent in ways which can be properly designated as language. But the fullness of development of each of these attributes in the human as contrasted with its development in any of the brutes is such that no one ever fails to distinguish the lowest living human from the highest living brute. When we come to scrutinize closely these two differences, the free hands and language—we find the bipedal form and habit of the human as contrasted with the quadrupedal form and habit of the brute and likewise the linguistic power of the human as contrasted with the brute are both inseparably connected with the fact that the activities of brutes are predominantly hereditary; that is, are performed according to plans and methods passed along from parents to offspring in the same way that plans of physical organs and parts are passed along. On the other hand, with humans we find the activities not predominantly hereditary. That is to say, they are not inborn but have to be acquired, learned afresh by each individual. We express this difference by calling the activities of brutes mainly instinctive and those of humans mainly rational and intelligent. Brute animal activity is largely instinct while human animal activity is largely on the basis of intelligence and reason.

When civilized man is reached in the evolutional scale the eons old struggle for existence takes the form of the struggle of mankind for and on the basis of ideas and ideals. These ideas and ideals are natural by the same token that sensations, reflex actions and instincts are natural—that token being that all alike belong in deepest essence to the very nature of man.

About the most convincing sign that an attribute of any living being is natural is its adaptability. An attribute's adaptiveness is that by virtue of which it contributes to the fitness of the being to live in the surroundings in which its life is set.

The fact of natural origin—origin by birth and growth—and of natural adaptiveness imply that adaptation is never absolutely perfect, hence forever needs improvement, is forever open to progress. It is demonstrated by observations on the activities of brute animals and

of primitive men as they live in nature that the imperfection of adaptiveness to conditions of life under purely sensory and reflexive activity is very serious. In fact it is so serious that great injury, even great destruction comes to individual and race because of it. Indeed I believe it demonstrable that had not nature found a way of correcting the injurious activities to which purely instinctive behavior is ever liable, progress in animal evolution would have ended in such classes as insects and reptiles. But to find such correctives is a part of the very essence of organic origin and growth.

The great correctives found by nature are what we call reason and intelligence, essential elements in which are *Ideas* and *Ideals*. According to common conception ideas have their seat in the human brain, while ideals are seated first and foremost in the human heart.

This sketch of the part Science is playing and still more must play in the herculean task of producing a system of natural ethics, is now finished. But before leaving it I will try to compact into the limits of a last minute, the substance of what has been said.

Brute animal life became transformed into human animal life through the countless millenniums of struggle of all life to fit itself ever more completely to the conditions which make any life at all possible.

Victory, under the name humanity, finally crowned the struggle when and because of, the slow and painful acquisition by the coming victor of the power to wage the struggle on the basis of ideas and ideals instead of on the ancient basis of the purely hereditary, that is instinctive activity of his brute ancestors.

This new and higher form of the struggle as it occurs within and among the members of the human species gives what in broadest generality we name the Moral Law. And so it is that Moral Law is Natural Law, Natural Law in its application to man being the totality of the impulsions, the efforts, and the acts, by which mankind strives to attain its own highest good by making itself ever better fitted for living, whether in this or in any other world that may be its abode.

FIELD CROP YIELDS IN NEW JERSEY FROM 1876 TO 1919

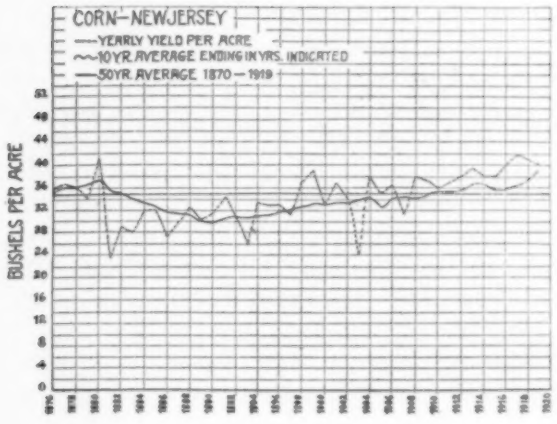
By HARRY B. WEISS

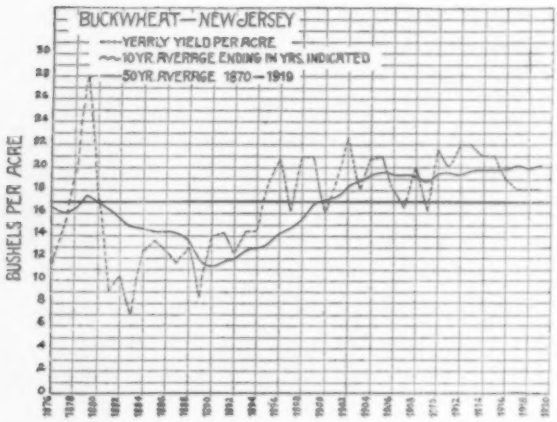
CHIEF, BUREAU OF STATISTICS AND INSPECTION, NEW JERSEY DEPARTMENT OF AGRICULTURE

WHILE New Jersey, on account of its extensive trucking areas, its peach and apple orchards, its plantations of small fruits, etc., is generally known as the "Garden State," as a matter of fact about 75 per cent. of its agricultural acreage is devoted to the growing of corn, wheat, rye, oats, buckwheat, potatoes, sweet potatoes and hay. In spite of its varied and intensive manufacturing interests and its growing suburban territory, its farms produced in 1920 over 11,000,000 bushels of corn, 1,500,000 bushels of wheat, over 1,000,000 bushels of rye, almost 3,000,000 bushels of oats, 2,000,000 bushels of sweet potatoes, almost 15,000,000 bushels of white potatoes and 545,000 tons of hay. It is entirely with these crops that the present paper deals, particularly with their average yields per acre from 1876 to 1919. A study of the yields over such a length of time should indicate at least in part either agricultural progression or retrogression and should afford some evidence as to the value and results of agricultural teachings over that period.

Of the factors controlling yields, climate undoubtedly is the most important and by climate is meant sunlight, the presence or absence of which influences the amounts of sugars, starches, fats, proteins, etc.; temperature, which influences germination, growth and in part the activities of soil bacteria and moisture or rainfall which determines the activities of soil bacteria and hence the availability of plant food. Only occasionally are all of the elements making up climate favorable for the plant over its entire period of growth and when this happens we have as a rule maximum yields and bumper crops. Climate as a whole can not be regulated, although by irrigation rainfall can be supplemented. By the selection of hardy species of plants some climatic effects can be overcome and by mulches, evaporation and therefore loss of heat from the soil can be reduced. For the most part however yields are at the mercy of climate.

Another important factor entering into yields and one which is controllable to a certain point is the fertility of the soil. The natural fertility can be added to by the use of commercial fertilizers and farm




BUCKWHEAT—NEW JERSEY
—YEARLY YIELD PER ACRE
~10 YR. AVERAGE ENDING IN YRS. INDICATED
—50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE

and green manures. The soil itself can be improved by the use of green and animal manures for the purpose of increasing the amount of vegetable matter and therefore its water holding power and bacterial activities. Increasing the yielding power by the addition of fertilizers is of course possible only up to the point where the law of diminishing returns starts to operate and other limiting factors are extra labor and material costs which must be considered together with the prices received for farm products.

Still another element is crop rotation. A good rotation favors high yields by utilizing plant food more evenly, by conserving moisture and regulating humus and by the prevention of rapid losses of fertility. In other words, one crop helps to prepare the soil for another or for the following one. Additional elements influencing yields are seed selection, preparation of seed bed, winterkilling, wind injury and the activities and control of injurious insects and plant diseases.

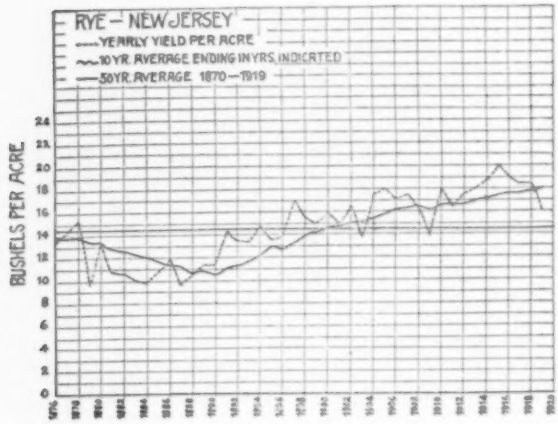
Having thus briefly and generally covered the more important factors bearing upon yields, let us turn our attention to the charts showing the curves of yearly average yields per acre, together with ten-year averages and the fifty-year average for the important field crops of New Jersey. The ten-year average curves are based on the yearly averages, this resulting in lines which are much easier to follow. It is with such curves that we will deal principally. As shown in the chart, the average yield of corn began to decline below the fifty-year average about 1883 and continued until 1890 when the lowest point was reached. From 1891 it rose slowly but not until 1909 or 18 years later did it reach the fifty-year average again. From 1891 however the ten-year average slowly increased. Buckwheat dropped below the fifty-year average line about 1881 and further declined until 1890 when it reached its lowest point. From then on it increased sharply until 1899, when the fifty-year average was reached and continued less sharply from that date. Rye began to decline in average yields in 1881 and reached a low level in 1890, after which it gradually increased. Wheat followed a course similar to that of rye. The ten-year average curve for oats shows little variation for the entire period. The hay curve shows a slight decrease about 1880 and continues down until 1889. From 1890 on it rises slowly. The potato curve shows little variation until 1902 after which date it climbs steadily. The sweet potato curve indicates a steady increase in average yields from 1878 on with the greatest rate of increase taking place after 1899.

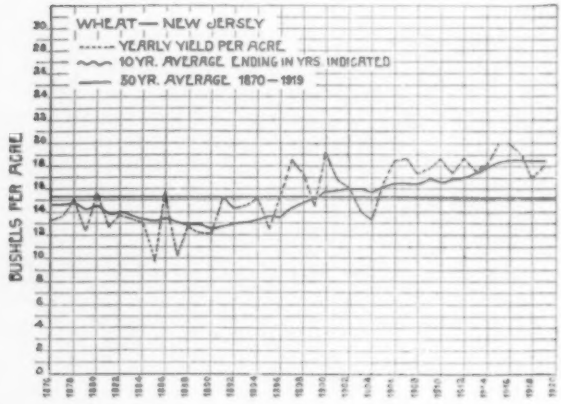
COMPARISON OF TEN-YEAR AVERAGE CURVES

Crop	Decline begins	Lowest point reached	Increase begins
Corn	1883	1890	1891
Buckwheat	1881	1890	1891
Rye	1881	1890	1891
Wheat	1881	1890	1891
Hay	1880	1889	1890
Potatoes (white)			1902
Sweet potatoes			1899

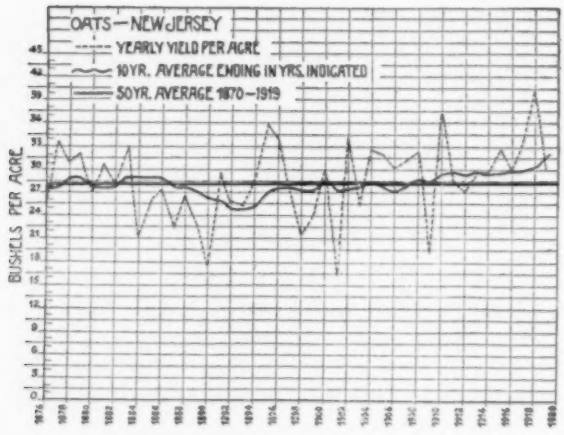
From 1880 to 1883 all of the above crops except white and sweet potatoes began to yield less, the lowest points being reached in the years 1889 and 1890. From 1891 on, the average yields of most gradually increased, potatoes, sweet potatoes and buckwheat at a faster rate than corn and hay.

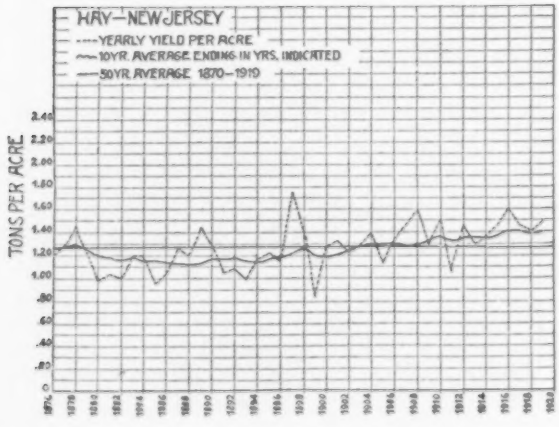
In an attempt to explain the causes underlying the dips and rises in the ten-year average curves, the climatic factor can be ignored. It is difficult to find any single definite reason which will account for the declines in the cases of corn, buckwheat, rye, wheat and hay from 1880 to 1890. It was suggested that a loss of the natural fertility might





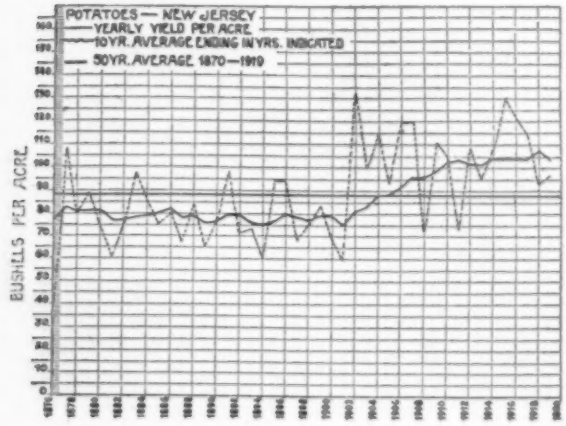
have taken place at that time but this is not possible because the cultivation of the soil in New Jersey was neither intensive nor long continued enough by 1890 to produce such a state of affairs. It was also suggested that this decline was probably due to the fact that the farmers at that time were not getting enough money for their products to warrant the purchase of fertilizers. A study of the prices received by New Jersey farmers for their products from 1866 to 1920 as shown by the chart in which corn, wheat and potato prices are plotted as fair examples, indicates that while prices from 1880 to 1890 were low compared with the prices for previous years, they were on the whole slightly higher than the prices received from 1900 to 1910 during which time more commercial fertilizers were being used and yields were increasing. However between the years 1880 and 1890 the prices of farm products were undoubtedly dropping faster than the prices of manufactured articles and such a condition would lead to retrenchment on the farms. Dr. Jacob G. Lipman, director of the New

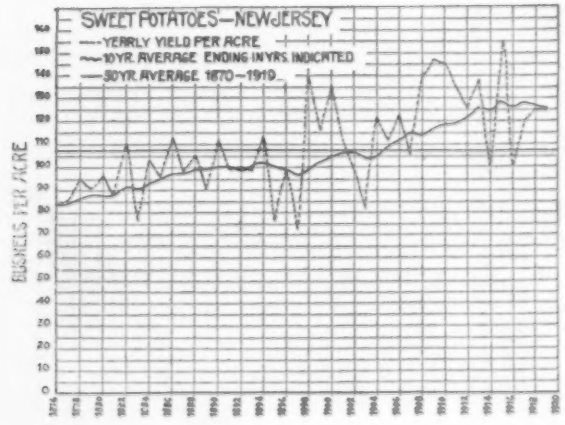




Jersey Agricultural Experiment Stations, informs me that the early '80's marked the end of the extensive use of greensand marl in New Jersey and that commercial fertilizers were just beginning to come in. With the discontinuance of the extensive use of marl after 1875 and the lack of familiarity on the part of the farmers with commercial fertilizers, there was naturally a period of depression in the fertility conditions.

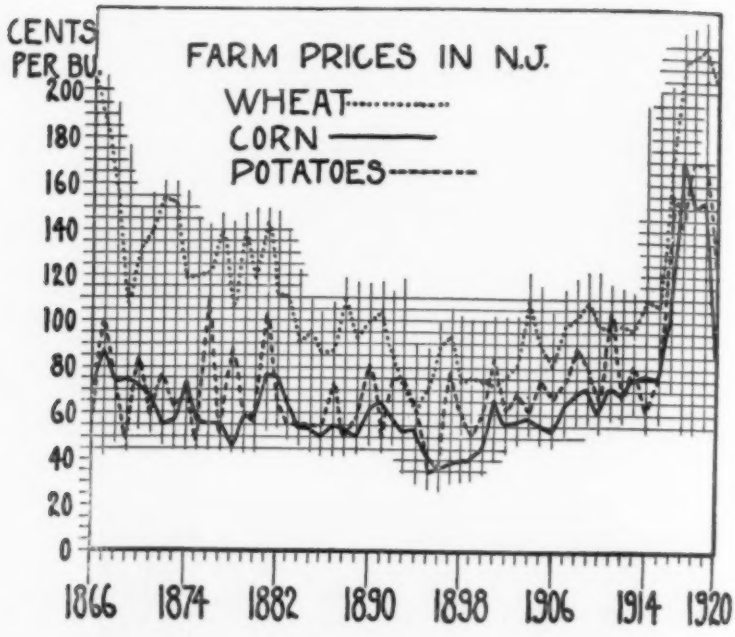
There is the additional fact to consider that in the early years statistics were not gathered as accurately as they were later, and in view of a lack of figures on which to compute ten-year averages before 1876 the declines between 1880 and 1890 may quite possibly be parts of a more or less natural cycle such as one might find when considering such variable items as yields and the factors influencing them over a long period of time. Moreover, for the most part, the declines are

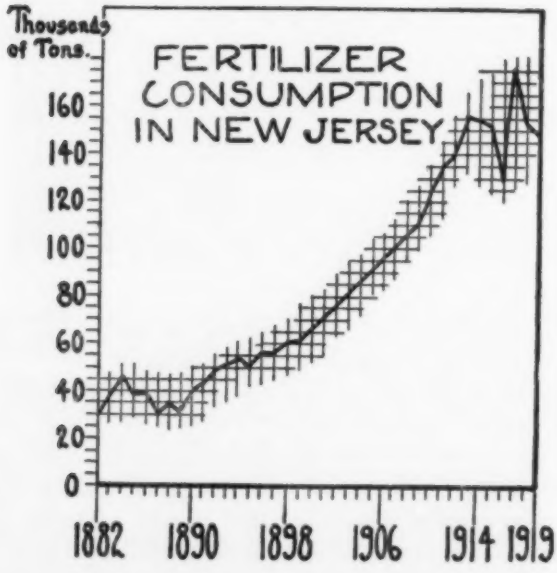



SWEET POTATOES—NEW JERSEY
YEARLY YIELD PER ACRE
10 YR. AVERAGE ENDING IN YRS. INDICATED
50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE

not startling as will be seen by examining the scale of the charts and may represent simply a low level in production.

The rises of the ten-year average curves are of more interest. These show no tendency to follow definite cycles arrangeable into up and down periods, at least not for the thirty-year period from 1891 to the present time. Practically all of them except the one for oats show a more or less gradual increase from 1891 on. In explaining the reason for this, some light may be thrown on the subject by noting the graph showing the rapid growth in the use of commercial fertilizers in New Jersey. The New Jersey Experiment Station was established in 1880 and its work in developing the knowledge of the use of commercial fertilizers is one of the outstanding services that it has rendered. From 1882 to 1890 the nine-year average consumption was about 36,000 tons. From 1890 on, the tonnage gradually increased until at





the present time about 150,000 tons are used each year. At present there is a more or less marked tendency toward the use of more concentrated fertilizers, which means that a smaller tonnage is furnishing the same amount of plant food formerly furnished by a larger tonnage. The curve of fertilizer consumption from 1890 on fits in nicely with the ten-year average crop yield from that date and it is

reasonable to assume that such fertilizers are in part responsible for the increase in average yields. This is especially true for potatoes on which comparatively large applications are made and to a less extent for sweet potatoes. Both are cash crops.

About 75 per cent. of the fertilizer tonnage is used in the southern two-thirds of the state and some of this is used for crops not considered in this paper. It is in this section that the bulk of the white potato and all of the sweet potato crops are grown. North of where most of the commercial fertilizer is used, are found the bulk of the wheat crop, about one-half of the rye and practically all of the oat and buckwheat crops. Corn and hay are generally distributed over the entire agricultural section of the state. The slow rate of increase in hay yields is undoubtedly due to the fact that in the usual rotations practiced in New Jersey, hay follows such crops as corn, potatoes and wheat and does not receive fertilizer applications to the same extent as other crops. Oats not being a cash crop would naturally receive less attention than the others and this accounts for the little variation in the ten-year average curve. In the potato, sweet potato and tomato sections of the state, other crops like corn and grass are the beneficiaries from the use of large amounts of fertilizers. Buckwheat, which is a minor crop, has received little or no attention in the way of improvement. It is a crop which yields well on poor land. According to the chart this crop shows a somewhat higher rate of yield increase than the others. This is due to the fact that it has ridden in on the crest of the improvement wave and its success insofar as increased yields are concerned is due to the improvement which took place generally.

In addition to the increased and intelligent use of commercial fertilizers, which appears to be the most important factor, other factors which have played their parts in helping to increase yields and which are of varying degrees of importance, are improved methods of soil management, seed selection particularly in the case of corn and potatoes during the past few years and increased efficiency in controlling injurious insects and plant diseases. It may also be noted that the introduction and extension of the acreage of alfalfa and the more intelligent growing of other legumes have played a part in the improvement of the productive power of the land. Some of the more common legumes, like soybeans, cowpeas, crimson clover, alfalfa and vetch, have been introduced into the state since 1880, although small acreages of some were known before that date.

These increases in yields can be taken as part of the evidence that farming is becoming more efficient and credit is due to all agricultural agencies in the state which have contributed toward this result by advocating and striving to advance new or better methods.

THE PLAY OF A NATION

By Professor G. T. W. PATRICK
UNIVERSITY OF IOWA, IOWA CITY

IF we use the term play quite broadly to include all forms of sport, recreation and relaxation, then it is evident that in work, sleep and play most of our time is spent. Excepting the very young and the very old, we sleep on the average about eight hours of the twenty-four. Most of us work at something or other eight or ten hours, more or less. This leaves six or eight hours for recreation and relaxation.

Of course there are other ways of passing the time not strictly included either in work, sleep or play, such, for instance, as eating and love-making, the latter, although a serious and instinctive form of behavior, often infringing upon or wholly absorbing the hours claimed for recreation.

Even at the worst, however, a good many hours of every day, say two, four, six, eight, ten, are spent in some form of play. Since we in America number more than a hundred million people, it follows that a good many hundred million hours are daily spent in something which goes by the name of play, be it recreation, relaxation, sports or pastimes.

Now there are certain psychological laws by which the value of play may be tested, enabling us to say in advance to what extent it is real play having restorative and recreational value. In the light of these laws, it will be interesting to study the actual plays of our American people, for our national health and our social welfare, as well as our personal health and happiness, depend a good deal on the character of our play.

When we think of our national sports, baseball comes to our minds —and football and basketball and golf and tennis. When we think of our recreations, perhaps music suggests itself or the theatre or special individual pursuits and interests. When we use the word play, probably we visualize children at some indefinite game—say hide-and-seek.

But a moment's reflection will show us that in the lives of our hundred million people the time actually spent in any of the above pursuits is very little. Evidently, if this study is to be of value as a social survey, we shall have to be more concrete, or even get into a statistical mood.

How then do we as a people actually pass our hours of recreation or relaxation? Well, some of us read, say newspapers or magazines or books of fiction, some of us smoke or even drink, some make social calls or just lounge and chatter, some simply sit, some talk or fuss or gossip, some play pool or billiards. A very large number go to the movies. Some play bridge. Some play poker or shoot craps. Some bet on baseball, football, or horseracing. Many ride in motor cars. Occasionally one or two ride horseback. A few walk. A very few swim or exhibit themselves in scanty costumes with the ostensible purpose of swimming. Once in a while one may go to the gymnasium. Some play golf or tennis. A large number dance. A few go fishing or hunting or camping. A certain number actually participate in baseball, football or basketball.

This is not intended as a complete list of our recreational activities but may afford a basis for the present study.

We in America live rather a tense life, under high pressure. Our diversified interests, our many social duties, our multitudinous responsibilities, our insistent worries, even our stimulating climate combine to make our modern life very strenuous, taxing our minds and bodies to the limit. Many succumb to the rapid pace and neuroses of various forms increase. In a way we are all at the front and in the trenches and shell shock is getting to be pretty common. Hence, the need of relaxation, recreation and play. Psychologists, social workers, religious workers and employers of labor have all awakened in recent years to the importance of play.

But play in order to be recreative must conform to certain requirements. All plays are pastimes but not all pastimes are play. Some of them seem merely to satisfy a longing for excitement. Why is it, since our whole modern life is so exciting as compared with former ways of living, that in our leisure hours we seek exciting pastimes? Why the craving for gambling, for alcohol, for tea and coffee and all sorts of stimulants? Why do we not seek rest and complete relaxation—a letting down and slowing up of our rapid pace? Why the demand for stimulating drinks, stimulating moving pictures, stimulating risks in gambling, stimulating speed in driving? Why the dancing craze and the amusement craze which at first sight would seem to increase our fatigue rather than allay it?

Fortunately the psychologists have worked out the problem for us and we now understand fairly well the psychology of play. We have learned that it is not excitement that we seek in play but release from those forms of mental activity which are fatigued in our daily life of grind. Play, if it is to be real play, that is if it is to have recreational value, must be of a sort to relieve those parts or tracts of the brain which are overtaxed in our daily life of work and worry. It must be

essentially different from our work, opposite in every respect. The work-a-day world of the present involves certain mental processes which are comparatively late in development in the long history of human evolution, such, for instance, as concentration, analysis, abstract thought, sustained attention, sustained effort, and controlled association, while the exigencies of our social life demand the constant checking or inhibition of a vast number of natural impulses and appetites.

The result is that that manner of cerebral functioning with which these higher intellectual and volitional processes are associated is brought under a severe stress and strain, leading to rapid neural fatigue and an urgent demand for rest and relaxation. It is not more sleep that is needed, nor rest of the whole body and brain, but relief from that special kind of activity so stressed in our modern competitive life. It is probably just for this reason that we crave alcohol and tobacco because they are not stimulants but narcotics, putting a temporary quietus upon just these overworked forms of cerebral activity.

Figuratively speaking, we may say that what is needed is that kind of activity which will relieve the higher brain centers, while allowing the older and lower ones to function. This is not strictly accurate from our present day conception of the brain. What really happens when we think hard, pay attention closely, decide quickly, or hold our mind steadily to a given task, is better expressed as a kind of total integration of cerebral processes, these processes taking the form probably in all cases of reflex arcs or reaction arcs, as we now call them. This total integration of brain processes is impossible for children and extremely fatiguing for adults. Children therefore must play all the time and grown-ups much of the time, if break-down is to be avoided: and by play we mean here some form of activity which does not involve this total integration of the brain areas.

Play then to be wholesome and truly recreative must involve only those areas of the brain and those parts of the nervous system which in the evolution of man are old and pervious and easy. They are, so to speak, the brain channels which are deep-worn and natural. The muscular responses in play must be those which past ages and long usage have made easy and familiar. We see, therefore, why the plays of children repeat the life history of the race. The cave, the tree-house, the swimming pool, the camp-fire, the bow and arrow, the canoe, the jack-knife, the ball bat, the mimic fight, kites, tops, marbles, hunting, fishing, gathering nuts, the cat, the dog, the teddy bear, the horse-race, the game of hide and seek, the charms and talismans and superstitions—all these are, as it were, reminiscences of the past life of the human species. They involve brain patterns that are old and familiar, the only ones in fact that are developed as yet in childhood

and the ones that in adult life give rest and release from the fatiguing activity of the higher brain centres continually stressed in our daily life of grind.

As a rough rule we may say that the more primitive a sport is the higher its recreational value. Good sports, therefore, are those which involve these older brain patterns and this criterion we can use in judging the recreational value of our sports and pastimes today.

The elements of rivalry, competition, and contest, as ancient forms of self-expression, act as purifying motives in all good sports. When these are absent, as in the moving pictures, the dance, and the automobile, the recreational value of the play falls off a little. In human society, especially in our modern crowded social groups, we are obliged to live together in peace and harmony and have to inhibit and suppress a great many of our natural and ancient feelings of rivalry and hatred. This constant suppression of our egoistic impulses results in many serious mental complexes. Games of rivalry thus provide a compensatory element, purifying the mind. This explains why there is so great a demand for games in which this element of rivalry takes a very direct and primitive form—the form of a regular face to face battle—as in prize fighting and football, and we understand why immense crowds flock to these sports.

I know a husband and wife who live together in great peace and happiness. They play once a day a game of backgammon in which all their pent-up and unconscious animosities are given full expression. During the time of this game they exhibit the most ruthless antagonism, showing no mercy to their opponent but bent on his complete destruction and annihilation. It is a fight to the finish.

But there are other rules by which to measure the value of our play. Since our modern work-a-day world, at least in our American climate, is to a large extent sedentary, confined and indoors, our sports to be of the greatest value must be out-of-door sports.

Finally, our sport must provide for self-expression. In self-expression there is a mystical recreational power. Nothing rests one so much as victory, pursuit and capture. All good games introduce the element of rivalry.

Now, equipped with these tests and measures of good play, sports, and pastimes, we are prepared to examine the actual recreations of our American people to see whether they stand the tests. And we have already discovered what these sports and pastimes are and have only to enumerate them again. If we attempt to name them roughly in the order of their prevalence, the order would seem to be something like this: Reading, movies, dancing, motoring, walking, card games, pool, baseball, golf, tennis, football, basketball, swimming, fishing, hunting, camping, gymnastics, and horseback riding. Such a classification must

be very general and even the most popular of these pursuits might be surpassed in popularity by other less definite forms of recreation or relaxation such as sitting, talking, gossiping, fussing, lounging, smoking, drinking, gambling, shopping, etc.

Applying our tests to these forms of play, it becomes clear at once that golf, tennis, baseball, football and basketball stand out pre-eminently as real recreative sports. From the psychologist's point of view, golf may be cited as the perfect ideal sport. It has all the needed recreational elements. It has a restorative power excelling all therapeutic arts. It represents a reversion to the natural outdoor life. We range over hills in the open, using the muscles of the legs, arms, and trunk. We carry a club and strike viciously at a ball. We search for the ball in the grass as our ancestors searched for their arrows. There is a goal and the spirit of rivalry and a chance for self-expression. The nerve currents course through ancient channels. We return to our work refreshed and rejuvenated. Golf, to be sure, requires fine adjustments of eye and hand at the moment of striking but there is no continuous strain upon them and skill of this kind is a proper element in play. It is unfortunate that the opportunities for golf are now limited to the few. Nothing better could happen to our nation than a wide extension to our people of the opportunities to play golf.

As regards tennis much the same may be said. Though lacking some of the distinctive psychological elements of perfect sport possessed by golf, it is still a very excellent and healthful form of recreation. Opportunities for it should be widely extended.

Baseball and football have certain peculiar qualities which rank them as high or possibly even higher than golf. Being more strenuous, they are better suited to the young males, while golf and tennis may be played by all. We see at once that football meets all the conditions which we have outlined as marks of good sport. There is running, kicking, dodging, tackling, pursuit and capture. There are also the opposing groups, as in battle, and the rough rude shock of personal collision. All these ancient responses offer complete relaxation and release from the proper and pent up inhibitory life of our modern world. They arouse latent, deep-seated instincts and impulses, allow us to revel for an hour in these ancient memories and restore us to our work refreshed and purified. It is the grip upon us of that which is racially old which explains the immense throngs which gather at the football games. Seventy or even a hundred thousand spectators have been reported at some of the great games.

The racial elements in baseball are not quite so old but are sufficient to permit the *catharsis* element in rare degree. Striking and throwing are dear to every boy, and these ancient responses, the ancestral conditions of race survival, are dominant in baseball, while the running and

catching, and the opposition of the teams, and the reward of skill and of strength and quick decision add to the real recreational value of the game. The recent extension of non-professional baseball and football among school boys is a contribution to social welfare. Here again, however, the application of the statistical method awakens our concern. For if baseball is fitted to all young men from the ages of fourteen to thirty, actual regular participation in it will be found to be limited to relatively few. It should be extended to a larger number.

But professional baseball as a national sport presents a different problem. Here the "players" are not playing but working. The game is a profession, a strife for glory and for money. The recreational features are now transferred to the spectators. To what extent is baseball of recreational value to the fans? They usually ride out to the ball park in auto or street car, sit on the bleachers during the game and return as they go. Nevertheless the game has considerable recreational value for the spectator. The galling social checks and inhibitions of the daily grind are thrown off for a time. Free expression is given to one's feelings and enthusiasms. There is a mental participation in the game and no doubt usually a considerable degree of rest and relaxation is gained. But it does not permit of self-expression and is far from an ideal form of play and at the best the number enjoying it is relatively small. Basketball, though lacking in some of the distinctive recreational elements of baseball and football, is nevertheless of the greatest value as a sport and stands high in our list.

Hunting and fishing, swimming and camping constitute a group of sports which rank high in the list of valuable recreations. They represent a return to the conditions of primitive life and involve only racially old and familiar brain patterns. They are out-of-door sports, using the fundamental muscles of the arms and legs and completely releasing the strain upon the eye and hand and nervous system. Hunting with the camera, recommended by the humane societies, is well enough, but the camera it not a substitute for the gun in recreational value. When we consider the horrors of the late war and remember that if the nervous tension of a people gets too high it may overflow in an actual orgy of human bloodshed, the "cruelty" of hunting and fishing seems less serious, especially if they act as a release of the nervous tension increased by our high pressure modern life.

Swimming as a form of play stands very high. It is unfortunate that so fine a sport should be degraded by the entrance of other elements, such as sex and dress, which detract from its pure recreational value. On the whole the reviving interest in swimming, bathing and camping, in the Boy Scout movement, in the Campfire Girls' movement, and in the whole outing cult in general, is a most encouraging sign. These are healthy forms of play.

But here again, if we count noses, how many of our hundred million people are able to avail themselves of these sports? The relative number of those who actually do engage in any of them sufficiently often to serve the purpose of recreation adequately is rather small. Opportunity for them is lacking among the greater number of our people both young and old. One-half of our whole social group, namely girls and women, are at once debarred from participation in most of the sports thus far discussed, excepting only tennis and swimming and perhaps golf.

We have therefore to consider now the value of the forms of recreation in which there is actual participation by large numbers of our people of both sexes, young and old. Motoring first demands our attention. As there are more than eight million automobiles in the United States, as most of these are kept pretty busy through many if not all months of the year, as each one may carry several people of both sexes, old and young, and as a considerable proportion of this riding is for purposes of recreation, we see at once that we have here a form of play of very wide extension. What is its value as determined by our psychological tests? Well, it is out-of-doors at any rate. Fresh air is furnished in abundance, and for our indoor workers that is certainly something. Man is by nature a roamer. He resents confinement. He must have a change of scene. He loves adventure. For old men and house-pent women the motor car is a boon. For workers whose daily tasks keep them on their feet, the automobile is a rest and comfort. It has also another recreational feature, namely, speed. The craving for speed, which gives zest to coasting, skating, and flying, is probably a survival of the ancient joy of pursuit and escape.

Nevertheless, for the average man and woman, and especially for the child, the automobile is anything but a blessing as a form of play. For hundreds of thousands of years the human being has lived on his feet and made his living by means of his legs. Now he has become, to a considerable extent, a sitting, lounging, reading, studying, and thinking being, and a whole group of new diseases has followed this sedentary life. It is by no means certain that a sitting race can survive. The motor car deprives many people of the little walking which they would otherwise do. Each new car advertises softer cushions, an easier upholstered back to support the shoulders or even the head, and more delicate springs to ward off every jar. The ease is seductive and we ride even to our offices or places of business.

With horseback riding the case is wholly different. Here, to be sure, the legs are not used, but a whole series of valuable psychological factors are present which make this one of the best of all sports. The horseback rider does not need the offices of the osteopath or chiropractor; his spinal column gets the necessary limbering up; and the

mere association with horses adds a subtle historical element of the greatest value. The automobile is suitable for convalescents.

Walking is not usually classified as play. It is nevertheless of exceedingly great value as a means of recreation for sitting people. It lacks many of the prime features of play but it is at any rate always available and may easily be a life saver.

So we come in the end to the dance and the moving pictures, for we may leave out of consideration a long list of recreations whose value the reader may easily appraise by using the tests which have been enumerated, such for instance as pool, billiards, card games, reading, gossiping, gambling, etc.

If, as we are told, twenty million people, men, women and children visit the movies every day, we have at least one form of recreation which even by the statistical method actually reaches the whole population without distinction of age, sex, or social status. The moving picture theater is everywhere, in the large city accessible almost without the use of a street car, in the country town more prominent than the church and school house. The price of admission is so moderate that the poorest may attend, while evening, afternoon, and Sunday exhibitions make the time convenient for all.

The dance is not quite so universal as the movies but is widely enjoyed by both sexes in city, town, and country.

What is the recreational value of these two universal forms of play? If we refer again to our table of tests, it would seem that the dance meets all the conditions except the out-of-doors requirement. It is an ultra-primitive form of human activity, as old as mankind itself. It relieves completely the strain upon the eye and finger muscles, involving only the ear and the larger muscles of the trunk and legs, the rhythmical movements being ancient, easy, and natural. The higher brain centers are completely rested, for they have nothing to do. The brain patterns of the dance are the simplest conceivable, being very old and familiar. There is a thrill of cherished memories associated with the dance in the life history of the race. This explains in part its fascination. When social restrictions are lifted, the craze for dancing bursts upon a sitting and sedentary race almost with the furor of an epidemic. A tired and nervous people finds here its release, a relaxation complete and satisfying. There is opportunity also for self-expression.

The more primitive the manner of dancing becomes the greater its charm. The recent revival of barbaric syncopated forms of music to accompany the dance and the still further reversion to steps and attitudes of the most primitive type heighten the joy and accentuate the recreational effects.

But it is right here that we encounter certain serious difficulties with

the dance as a means of recreation. We live in highly complex social groups, in which other factors than merely physiological and psychological ones count. The social and moral aspects of every form of recreation have to be considered. The modern dance owes its attractiveness, not wholly but partly, to the sex motive. To that extent it passes out of the sphere of play activity into the wholly different sphere of love-making. As such it does not come within the purpose of this paper. This mixture of motives, however, very greatly lessens the value of the dance as a form of recreation, excepting of course the graceful and healthful forms of folk dancing, the revival of which is a sign of hope.

Still other factors lessen the value of the dance as recreation. Not only is it indoors; it is largely a night pastime and has incidental associations of late hours, extravagance in dress, and moral surroundings not always good. On the whole, it may probably be said that while from the standpoint of the individual the dance in itself has unlimited possibilities as recreation, from the standpoint of social health and welfare the results are bad.

If we consider the esthetic dances and the esthetic factor in all dancing, a point in favor of the dance may be urged. No recreational force could be imagined better for a spent and nervous people than the enjoyment of beauty in all its forms. Could the attention of the American nation be diverted for certain hours of the day or week from its feverish pursuit of wealth and power to the quiet enjoyment of beautiful things, its salvation would be insured. Of all the forms of esthetic enjoyment, that of music is the most restful, harmonizing, and tranquilizing. And this is not altogether due to the intrinsic excellence of music over the arts of painting, sculpture, architecture and poetry, although even that claim might be urged. The restful and recreational value of music for our people is due in a peculiar way to the fact of our prevailing eye-mindedness and finger-mindedness. In music we find our release. It is thus a hopeful sign for the permanence of our civilization that in our public schools a constantly increasing time is given to music and the other fine arts.

The compensatory character in play which we have emphasized is incidentally well illustrated by the wave of jazz that has swept the world and now spent itself. Ethically and esthetically no music could be worse than this. But as a temporary restorative of nerves shattered by a terrible world war, no music could be better. For the moment the world needed a complete release, a primeval pacifier. It seized with joy upon the music and the dance of primeval man and perhaps for the same reason has reverted in other ways to primeval practices and morals. Having thus been flushed and purged, the toiling upward way may again be undertaken.

As regards the movies, one point in their favor has been noted. They are accessible and available. They satisfy vicariously the love of adventure, the roaming instinct, the delight in the new and the strange and the wonderful. They are absorbing, diverting the weary soul from its troubles. They relieve the strain upon the will by the plot-interest, which carries the observer along without effort. They bring a glimpse of fairy land into some lives that are drab and prosy. Those who cannot even dance may here participate in the sight of dancing. To those who have no beauty in their daily surroundings, beauty is brought in many forms upon the screen.

But when this is said, all is said, for if we refer again to our table of tests of recreational factors, we find nearly all the elements of good play wanting in the movies. Good play is out of doors and involves the larger fundamental muscles of the trunk and legs, and for children this is primary and indispensable. They must be active in play and all sedentary people must be active in play. It is bad enough that children should be confined in a school-room five precious hours of the day. It is worse if they are penned in between a desk and a seat. For such children to spend still other hours of the day or evening or any hours of their holidays in confinement is serious, and especially in these days of universal reading, when old and young alike spend so many hours sitting, reading fascinating books of fiction, and interesting magazines and papers.

In the moving picture theater the bodily confinement is complete and uncompromising. In the school-room the child can at least wriggle. In the movies the attention is so wrapt as to result in a statue-like rigidity of the whole body for hours. For adults this is unfortunate; for children it is fatal. Many moving picture theaters are stuffy. Most of them are crowded. The physical conditions are thus the worst possible from the standpoint of recreational needs.

As regards the use of the sense-organs, the eye, overworked among our modern reading people, gains no rest from moving pictures but is taxed to the very utmost and kept under strain for hours. To what extent the eyes will suffer from the moving pictures I am not here discussing. I am only pointing out the failure of the movies to conform in this respect to recreational requirements. The relations of the eye and ear to our modern life are such that good music is of far greater value as recreation and relaxation than any appeal to the eye. If our play is to take the form of any entertainment on the stage, good music in any form, whether in concert, recital, folk songs, or opera, would seem to be deserving a very high place.

Incidentally it should be mentioned here that in the history of the race the most intimate and human relations are associated with the voice as used in speech. The Greek tragic drama, which drew whole

populations of a city to the outdoor stage, depended for its powerful appeal largely upon the human voice. The spectacular character of the modern theater seems like a distinct loss. But when this is carried, as in the moving pictures, to the point where human life and society are wholly divorced from the expressive and meaningful tones of the voice, we seem to be living in a dessicated and dehumanized world, from which all intrinsic worth has departed. The visual world depicted on the screen has movement, plot-interest, strangeness, novelty, excitement, intensity, but lacks the elements which are soothing, tranquilizing and harmonizing. It is neither relaxation nor recreation.

Another aspect of the moving pictures in their relation to the human mind, which must be taken into account, is their effect upon the emotions. Aristotle's catharsis theory of the drama has been long discussed. The mind is supposed to be purified by such mild excitement of the emotions of pity and fear as is offered by the tragic scene upon the stage. Our pent up emotions are supposed to demand expression and the drama serves as a kind of safety-valve, allowing the emotions a legitimate and harmless outlet.

There is scant psychological evidence to support this theory. The emotional flooding of the mind which the spectator experiences probably has no recreational value in itself. In the legitimate drama this tumult of the emotions, tempered by the human voice and by all the settings of real art, may be for the adult a harmless accompaniment of esthetic enjoyment. In the moving pictures such frequent and excessive overflow of the emotional life can hardly fail to disturb the delicate balance between real life and its natural emotional response. Certain films widely exhibited to large audiences draw too heavily upon the emotions. Old time revivalists have been censured for working upon the feelings of their hearers by appeals to the very intimate and personal experiences connected with birth, death, and marriage. These tales were innocent compared with the harrowing scenes sometimes presented on the screen. Tears flow and the breast heaves but the natural expression of emotional states through action is prohibited. In real life such emotional situations lead to action. In the movies nothing happens. The natural response is lacking.

We must conclude therefore that from the standpoint of the psychology of play, the movies offer little of recreational value, while for children they may be the source of the most pernicious mischief. The physical decadence which is anyway threatening our people because of our modern life of comfort, ease, and inactivity, with its excessive demands upon the brain and its neglect of physical development, is likely to receive a considerable impetus from the moving pictures.

As I am speaking here of recreational values only, I need not dwell on the moral influence of the movies. Neither can one pass the sub-

ject in complete silence. From this point of view one needs stronger phrases than "a national calamity" and "the world's worst failure," which have recently been applied to these pictures.

Hitherto humanity by tacit and universal consent has been willing for the sake of the innocence of its children and the purity of its women to draw a veil before the worst evils of the world, and by a delicate instinct to touch lightly and reverently upon its most sacred institutions. It has always been assumed that there are some things too sacred, some too intimate to be exposed to public view. But in the moving pictures all is cheapened. The veil is ruthlessly torn from everything, and for commercial motives only.

The pernicious effects of flaming abroad to every town and countryside moving pictures of the most decadent phases of city life must be apparent to everybody, but to introduce our young children to all this seems like social suicide. The plot-interest of a cheap play we enjoy for an hour but the plot-interest in life itself is discounted in advance and deadened. The moving picture concerns say that the public demands sensational and erotic pictures. That an enlightened social community should allow great commercial interests to exploit its children for motives such as these is beyond belief. Certainly we are a complacent people.

When society comes to its senses and sweeps the bad pictures from the stage, then the question of the recreational and educational value of the movies will be more carefully raised. The recreational value, as we have seen, is slight, while the educational value has been greatly overestimated. The child, as any educator knows now, learns by doing, not by seeing. The moving pictures may bring to the child a visual image of many things but what is more important is that he himself should learn to contribute to human utilities, that he should take his part in life, that he should learn to control himself, to express himself, to read and write and speak correctly, that he should know how to appreciate good language, good books, good music, and good art, that he should conduct himself as a responsible moral being in the family and in the social group. These things cannot be learned by seeing them on a screen. They must be learned by long and persistent training in the actual doing.

In conclusion, it would seem that in regard to the actual present day recreations of the great body of our American people, the three which rank highest in respect to the numbers participating in them, namely, the dance, the movies, and the automobile, do not rank high in real recreational value while one of them has a doubtful social value, and one a widespread pernicious influence.

Mr. Chesterton says that our modern people do not know how to amuse themselves because they are not free men. Our amusements are

mechanical, as our whole life is. We have to be amused by machinery, such as the cinema and the automobile. True recreation is that in which we ourselves participate. There must be action and self-expression.

It will not do to lay all the evils of the present time—and they are very threatening—upon our institutions nor upon the war. To a considerable extent they have their source in the unstable brain of the individual. Our material and social environment is changing very rapidly while the human brain and body are changing little or not at all. Hence, we are not adjusted to our environment and social irritability results, venting itself usually in an attack upon our political institutions.

Nothing would do more towards the solution of our social problems than providing healthful and harmonizing recreations for the nation. The way to do this may be beset with difficulties but the true approach seems to be through the public schools. The cultivation of good taste in selecting our amusements would do something, but practical results will be more likely to follow the enlarged opportunities for good sports and healthful plays and a revision of our school program in the direction of the English system, in which sports and play are an integral part of the public school curriculum.

EVARISTE GALOIS

By Dr. GEORGE SARTON
CARNEGIE INSTITUTION

NO episode in the history of thought is more moving than the life of Evariste Galois—the young Frenchman who passed like a meteor about 1828, devoted a few feverish years to the most intense meditation, and died in 1832 from a wound received in a duel, at the age of twenty. He was still a mere boy, yet within these short years he had accomplished enough to prove indubitably that he was one of the greatest mathematicians of all times. When one sees how terribly fast this ardent soul, this wretched and tormented heart were consumed one can but think of the beautiful meteoric showers of a summer night. But this comparison is misleading, for the soul of Galois will burn on throughout the ages and be a perpetual flame of inspiration. His fame is incorruptible; indeed the apotheosis will become more and more splendid with the gradual increase of human knowledge.

No existence could be more tragic than his and the only one at all comparable to it is, strangely enough, that of another mathematician, fully his equal, the Norwegian Niels Henrik Abel, who died of consumption at twenty-six in 1829; that is just when Galois was ready to take the torch from his hand and to run with it a little further. Abel had the inestimable privilege of living six years longer, and think of these years—not ordinary years of a humdrum existence, but six full years at the time that genius was ripe—six years of divine inspiration. What would not Galois have given us, if he had been granted six more such years at the climax of his life? But it is futile to ask such questions. Prophecies too are futile, yet a certain amount of anticipation of the future may be allowed, if one does not contravene the experience of the past. For example, it is safe to predict that Galois' fame can but wax, because of the fundamental nature of his work. While the inventors of important applications, whose practical value is obvious, receive quick recognition and often very substantial rewards, the discoverers of fundamental principles are not generally awarded much recompense. They often die misunderstood and unrewarded. But while the fame of the former is bound to wane as new processes supersede their own, the fame of the latter can but increase. Indeed the importance of each principle grows with the number and the value of its applications; for each new application is a new tribute to its worth.

To put it more concretely, when we are very thirsty a juicy orange is more precious to us than an orange tree. Yet when the emergency has passed, we learn to value the tree more than any one of its fruits; for each orange is an end in itself, while the tree represents the innumerable oranges of the future. The fame of Galois has a similar foundation; it is based upon the unlimited future. He well knew the pregnancy of his thoughts, yet they were even more far-reaching than he could possibly dream of. His complete works fill only sixty-one small pages; but a French geometer, publishing a large volume some forty years after Galois' death, declared that it was simply a commentary on the latter's discoveries. Since then, many more consequences have been deduced from it, and Galois' fundamental ideas have influenced the whole of mathematical philosophy. It is likely that when mathematicians of the future contemplate his personality at the distance of a few centuries, it will appear to them to be surrounded by the same halo of wonder as those of Euclid, Archimedes, Descartes and Newton.

Evariste Galois was born in Bourg-la-Reine, near Paris, on the 25th of October, 1811,[1] in the very house in which his grandfather had lived and had founded a boys' school. This being one of the very few boarding schools not in the hands of the priests, the Revolution had much increased its prosperity. In the course of time, grandfather Galois had given it up to his younger son and soon after, the school had received from the imperial government a sort of official recognition. When Evariste was born, his father was thirty-six years of age. He had remained a real man of the eighteenth century, amiable and witty, clever at rhyming verses and writing playlets and instinct with philosophy. He was the leader of liberalism in Bourg-la-Reine, and during the Hundred Days had been appointed its mayor. Strangely enough, after Waterloo he was still the mayor of the village. He took his oath to the King, and to be sure he kept it, yet he remained a liberal to the end of his days. One of his friends and neighbors, Thomas François Demante, a lawyer and judge, one time professor in the Faculty of Law of Paris, was also a typical gentleman of the "ancien régime," but of a different style. He had given a very solid classical education not only to his sons but also to his daughters. None of these had been more deeply imbued with the examples of antiquity than Adelaïde-Marie who was to be Evariste's mother. Roman stoicism had sunk deep into her heart and given to it a virile temper. She was a good Christian, though more concerned with the ethical than with the mystical side of religion. An ardent imagination had colored her every virtue with passion.

[1] The biographical facts are borrowed from P. Dupuy's exhaustive biography, published in the "Annales Scientifiques de l'Ecole Normale Supérieure," t. xiii, Paris, 1896.

Many more people have been able to appreciate her character than her son's, for it was to be her sad fortune to survive him forty years. She was said to be generous to a fault and original to the point of queerness. There is no doubt that Evariste owed considerably more to her than to his father. Besides, until the age of eleven the little boy had no teacher but his mother.

In 1823, Evariste was sent to college in Paris. This college—Louis le-Grand—was then a gloomy house, looking from the outside like a prison, but within aflame with life and passion. For heroic memories of the Revolution and the Empire had remained particularly vivid in this institution, which was indeed, under the clerical and reactionary regime of the Restoration, a hot-bed of liberalism. Love of learning and contempt of the Bourbons divided the hearts of the scholars. Since 1815 the discipline had been jeopardized over and over again by boyish rebellions, and Evariste was certainly a witness of, if not a partner in, those which took place soon after his arrival. The influence of such an impassioned atmosphere upon a lad freshly emancipated from his mother's care cannot be exaggerated. Nothing is more infectious than political passion, nothing more intoxicating than the love of freedom. It was certainly there and then that Evariste received his political initiation. It was the first crisis of his childhood.

At first he was a good student; it was only after a couple of years that his disgust at the regular studies became apparent. He was then in the second class (that is, the highest but one) and the "provisor" suggested to his father that he should spend a second year in it, arguing that the boy's weak health and immaturity made it imperative. The child was not strong but the provisor had failed to discover the true source of his lassitude. His seeming indifference was due less to immaturity than to his mathematical precocity. He had read his books of geometry as easily as a novel, and the knowledge had remained firmly anchored in his mind. No sooner had he begun to study algebra than he read Lagrange's original memoirs. This extraordinary facility had been at first a revelation to himself, but as he grew more conscious of it, it became more difficult for him to curb his own domineering thought and to sacrifice it to the routine of class work. The rigid program of the college was to him like a bed of Procrustes, causing him unbearable torture without adequate compensation. But how could the provisor and the teachers understand this? The double conflict within the child's mind and between the teachers and himself, as the knowledge of his power increased, was intensely dramatic. By 1827 it had reached a critical point. This might be called the second crisis of his childhood: his scientific initiation. His change of mood was observed by the family. Juvenile gaiety was suddenly replaced by concentration; his manners became stranger every day. A

mad desire to march forward along the solitary path which he saw so distinctly, possessed him. His whole being, his every faculty was mobilized in this immense endeavor.

I cannot give a more vivid idea of the growing strife between this inspired boy and his uninspired teachers than by quoting a few extracts from the school reports:

1826-1827

This pupil, though a little queer in his manners, is very gentle and seems filled with innocence and good qualities. . . . He never knows a lesson badly: either he has not learned it at all or he knows it well. . . .

A little later:

This pupil, except for the last fortnight during which he has worked a little, has done his class work only from fear of punishment. . . . His ambition, his originality—often affected—the queerness of his character keep him aloof from his companions.

1827-1828

Conduct rather good. A few thoughtless acts. Character of which I do not flatter myself I understand every trait; but I see a great deal of self-esteem dominating. I do not think he has any vicious inclination. His ability seems to me to be entirely beyond the average, with regard as much to literary studies as to mathematics. . . . He does not seem to lack religious feeling. His health is good but delicate.

Another professor says:

His facility, in which one is supposed to believe but of which I have not yet witnessed a single proof, will lead him nowhere: there is no trace in his tasks of anything but of queerness and negligence.

Another still:

Always busy with things which are not his business. Goes down every day.

Same year, but a little later:

Very bad conduct. Character rather secretive. Tries to be original. . . . Does absolutely nothing for the class. The furor of mathematics possesses him. . . . He is losing his time here and does nothing but torment his masters and get himself harassed with punishments. He does not lack religious feeling; his health seems weak.

Later still:

Bad conduct, character difficult to define. Aims at originality. His talents are very distinguished; he might have done very well in "Rhétorique" if he had been willing to work, but swayed by his passion for mathematics, he has entirely neglected everything else. Hence he has made no progress whatever. . . . Seems to affect to do something different from what he should do. It is possibly to this purpose that he chatters so much. He protests against silence.

In his last year at the college, 1828-1829, he had at last found a teacher of mathematics who divined his genius and tried to encourage and to help him. This Mr. Richard, to whom one cannot be too grate-

ful, wrote of him: "This student has a marked superiority over all his school-mates." "He works only at the highest parts of mathematics." You see the whole difference. Kind Mr. Richard did not complain that Evariste neglected his regular tasks, and, I imagine, often forgot to do the petty mathematical exercises, which are indispensable to drill the average boy; he does not think it fair to insist on what Evariste does not do, but states what he does do: he is only concerned with the highest parts of mathematics. Unfortunately, the other teachers were less indulgent. For physics and chemistry, the note often repeated was: "Very absent-minded, no work whatever."

To show the sort of preoccupations which engrossed his mind: at the age of sixteen he believed that he had found a method of solving general equations of the fifth degree. One knows that before succeeding in proving the impossibility of such resolution, Abel had made the same mistake. Besides, Galois was already trying to realize the great dream of his boyhood: to enter the Ecole Polytechnique. He was bold enough to prepare himself alone for the extrance examination as early as 1828—but failed. This failure was very bitter to him—the more so that he considered it as unfair. It is likely that it was not at all unfair, at least according to the accepted rules. Galois knew at one and the same time far more and far less than was necessary to enter Polytechnique; his extra knowledge could not compensate for his deficiencies, and examiners will never consider originality with favor. The next year he published his first paper, and sent his first communication to the Académie des Sciences. Unfortunately, the latter got lost through Cauchy's negligence. This embittered Galois even more. A second failure to enter Polytechnique seemed to be the climax of his misfortune, but a greater disaster was still in store for him. On July 2 of this same year, 1829, his father had been driven to commit suicide because of the vicious attacks directed against him, the liberal mayor, by his political enemies. He took his life in the small apartment which he had in Paris, in the vicinity of Louis-le-Grand. As soon as his father's body reached the territory of Bourg-la-Reine, the inhabitants carried it on their shoulders, and the funeral was the occasion of disturbances in the village. This terrible blow, following many smaller miseries, left a very deep mark on Evariste's soul. His hatred of injustice became the more violent, in that he already believed himself to be a victim of it; his father's death incensed him, and developed his tendency to see injustice and baseness everywhere.

His repeated failures to be admitted to Polytechnique were to Galois a cause of intense disappointment. To appreciate his despair, one must realize that the Ecole Polytechnique was then, not simply the highest mathematical school in France and the place where his genius would be most likely to find the sympathy it craved, it was also a daughter of the Revolution who had remained faithful to her origins in spite

of all efforts of the government to curb her spirit of independence. The young Polytechnicians were the natural leaders of every political rebellion; liberalism was for them a matter of traditional duty. This house was thus twice sacred to Galois, and his failure to be accepted was a double misfortune. In 1829 he entered the Ecole Normale, but he entered it as an exile from Polytechnique. It was all the more difficult for him to forget the object of his former ambition, because the Ecole Normale was then passing through the most languid period of its existence. It was not even an independent institution, but rather an extension of Louis-le-Grand. Every precaution had been taken to insure the loyalty of this school to the new regime. Yet there, too, the main student body inclined toward liberalism, though their convictions were very weak and passive as compared with the mood prevailing at Polytechnique; because of the discipline and the spying methods to which they were submitted, their aspirations had taken a more subdued and hypocritical form only relieved once in a while by spasmodic upheavals. Evariste suffered doubly, for his political desires were checked and his mathematical ability remained unrecognized. Indeed he was easily embarrassed at the blackboard, and made a poor impression upon his teachers. It is quite possible that he did not try in the least to improve this impression. His French biographer very clearly explains his attitude:

> There was in him a hardly disguised contempt for whosoever did not bow spontaneously and immediately before his superiority, a rebellion against a judgment which his conscience challenged beforehand and a sort of unhealthy pleasure in leading it further astray and in turning it entirely against himself. Indeed, it is frequently observed that those people who believe that they have most to complain of persecution could hardly do without it and, if need be, will provoke it. To pass oneself off for a fool is another way and not the least savory, of making fools of others.

It is clear that Galois' temper was not altogether amiable, yet we should not judge him without making full allowance for the terrible strain to which he was constantly submitted, the violent conflicts which obscured his soul, the frightful solitude to which fate had condemned him.

In the course of the ensuing year, he sent three more papers to mathematical journals and a new memoir to the Académie. The permanent secretary, Fourier, took it home with him, but died before having examined it, and the memoir was not retrieved from among his papers. Thus his second memoir was lost like the former. This was too much indeed and one will easily forgive the wretched boy if in his feverish mood he was inclined to believe that these repeated losses were not due to chance but to systematic persecution. He considered himself a victim of a bad social organization which ever sacrifices genius to mediocrity, and naturally enough he cursed the hated regime of oppression which had precipitated his father's death and against which the storm

was gathering. We can well imagine his joy when he heard the first shots of the July Revolution! But alas! While the boys of Polytechnique were the very first in the fray, those of the Ecole Normale were kept under lock and key by their faint-hearted director. It was only when the three glorious days of July were over and the fall of the Bourbons was accomplished that this opportunist let his students free and indeed placed them at the disposal of the provisional government! Never did Galois feel more bitterly that his life had been utterly spoiled by his failure to become an alumnus of his beloved Polytechnique.

In the meanwhile the summer holidays began and we do not know what happened to the boy in the interval. It must have been to him a new period of crisis, more acute than any of the previous ones. But before speaking of it let me say a last word about his scientific efforts, for it is probable that thereafter political passion obsessed his mind almost exclusively. At any rate it is certain that Evariste was in the possession of his general principles by the beginning of 1830, that is, at the age of eighteen, and that he fully knew their importance. The consciousness of his power and of the responsibility resulting from it increased the concentration and the gloominess of his mind to the danger point; the lack of recognition developed in him an excessive pride. By a strange aberration he did not trouble himself to write his memoirs with sufficient clearness and to give the explanations which were the more necessary because his thoughts were more novel. What a pity that there was no understanding friend to whisper in his ear Descartes' wise admonition: "When you have to deal with transcendent questions, you must be transcendentally clear." Instead of that, Galois enveloped his thought in additional secrecy by his efforts to attain greater conciseness, that coquetry of mathematicians.

It is intensely tragic that this boy already sufficiently harassed by the turmoil of his own thoughts, should have been thrown into the political turmoil of this revolutionary period. Endowed with a stronger constitution, he might have been able to cope with one such; but with the two, how could he—how could anyone do it? During the holidays he was probably pressed by his friend, Chevalier, to join the Saint-Simonists, but he declined, and preferred to join a secret society, less aristocratic and more in keeping with his republican aspirations—the " Société des amis du peuple". It was thus quite another man who reentered the Ecole Normale in the autumn of 1830. The great events of which he had been a witness had given to his mind a sort of artificial maturity. The revolution had opened to him a fresh source of disillusion, the deeper because the hopes of the first moment had been more sanguine. The government of Louis-Philippe had promptly crushed the more liberal tendencies; and the artisans of the new revolution, who had drawn their inspiration from the great events of 1789,

soon discovered to their intense disgust that they had been fooled. Indeed under a more liberal guise, the same oppression, the same favoritism, the same corruption soon took place under Louis-Philippe as under Charles X. Moreover, nothing can be more demoralizing than a successful revolution (whatever it be) for those who, like Galois, were too generous to seek any personal advantage and too ingenuous not to believe implicitly in their party shibboleths. It is such a high fall from one's dearest ideal to the ugliest aspect of reality—and they could not help seeing around them the more practical and cynical revolutionaries eager for the quarry, and more disgusting still, the clever ones, who had kept quiet until they knew which side was gaining, and who now came out of their hiding places to fight over the spoils and make the most of the new regime. Political fermentation did not abate and the more democratic elements, which Galois had joined, became more and more disaffected and restless. The director of the Ecole Normale had been obliged to restrain himself considerably to brook Galois' irregular conduct, his "laziness," his intractable temper; the boy's political attitude, and chiefly his undisguised contempt for the director's pusillanimity now increased the tension between them to the breaking point. The publication in the "Gazette des Ecoles" of a letter of Galois in which he scornfully criticised the director's tergiversations was but the last of many offenses. On Dec. 9, he was invited to leave the school, and his expulsion was ratified by the Royal Council on Jan. 3, 1831.

To support himself Galois announced that he would give a private course of higher algebra in the backshop of a bookseller, Mr. Caillot, 5 rue de la Sorbonne. I do not know whether this course, or how much of it, was actually delivered. A further scientific disappointment was reserved for him: a new copy of his second lost memoir had been communicated by him to the Académie; it was returned to him by Poisson, four months later, as being incomprehensible. There is no doubt that Galois was partly responsible for this, for he had taken no pains to explain himself clearly. This was the last straw. Galois' academic career was entirely compromised, the bridges were burned, he plunged himself entirely into the political turmoil. He threw himself into it with his habitual fury and the characteristic intransigency of a mathematician: there was nothing left to conciliate him, no means to moderate his passion, and he soon reached the extreme limit of exaltation. He is said to have exclaimed: "If a corpse were needed to stir the people up, I would give mine." Thus on May 9, 1831, at the end of a political banquet, being intoxicated—not with wine but with the ardent conversation of an evening—he proposed a sarcastic toast to the King. He held his glass and an open knife in one hand and said simply: "To Louis-Philippe!" Of course he was soon arrested and sent to Ste. Pélagie. The lawyer persuaded him to maintain that he had actually said: "To

Louis-Philippe, *if he betray*," and many witnesses affirmed that they had heard him utter the last words, though they were lost in the uproar. But Galois could not stand this lying and retracted it at the public trial. His attitude before the tribunal was ironical and provoking, yet the jury rendered a verdict of not proven and he was acquitted. He did not remain free very long. On the following Fourteenth of July, the government, fearing manifestations, decided to have him arrested as a preventive measure. He was given six months' imprisonment on the technical charge of carrying arms and wearing a military uniform, but he remained in Ste. Pélagie only until March 19 (or 16?), 1832, when he was sent to a convalescent home on the rue de Lourcine. A dreadful epidemic of cholera was then raging in Paris, and Galois' transfer had been determined by the poor state of his health. However, this proved to be his undoing.

He was now a prisoner on parole and took advantage of it to carry on an intrigue with a woman of whom we know nothing, but who was probably not very reputable ("une coquette de bas étage," says Raspail). Think of it! This was, as far as we know, his first love—and it was but one more tragedy on the top of so many others. The poor boy who had declared in prison that he could love only a Cornelia or a Tarpeia[2] (we hear in this an echo of his mother's Roman ideal), gave himself to this new passion with his usual frenzy, only to find more bitterness at the end of it. His revulsion is lamentably expressed in a letter to Chevalier (May 25, 1832):

> . . . How to console oneself for having exhausted in one month the greatest source of happiness which is in man—of having exhausted it without happiness, without hope, being certain that one has drained it for life?
>
> Oh! come and preach peace after that! Come and ask men who suffer to take pity upon what is! Pity, never! Hatred, that is all. He who does not feel it deeply, this hatred of the present, cannot really have in him the love of the future. . . .

One sees how his particular misery and his political grievances are sadly muddled in his tired head. And a little further in the same letter, in answer to a gentle warning of his friend:

> I like to doubt your cruel prophecy when you say that I shall not work any more. But I admit that it is not without likelihood. To be a savant, I should need to be that alone. *My heart has revolted against my head.*[3] I do not add as you do: It is a pity.

Can a more tragic confession be imagined? One realizes that there is no question here of a man possessing genius, but of genius possessing a man. A man? a mere boy, a fragile little body divided within itself by disproportionate forces, an undeveloped mind crushed merci-

[2] He must have quoted Tarpeia by mistake.

[3] The italics are mine.

lessly between the exaltation of scientific discovery and the exaltation of sentiment.

Four days later two men challenged him to a duel. The circumstances of this affair are, and will ever remain, very mysterious. According to Evariste's younger brother the duel was not fair. Evariste, weak as he was, had to deal with two ruffians hired to murder him. I find nothing to countenance this theory except that he was challenged by two men at once. At any rate, it is certain that the woman he had loved played a part in this fateful event. On the day preceding the duel, Evariste wrote three letters of which I translate one:

May 29, 1832.

Letter to all Republicans.

I beg the patriots, my friends, not to reproach me for dying otherwise than for the country.

I die the victim of an infamous coquette. My life is quenched in a miserable piece of gossip.

Oh! why do I have to die for such a little thing, to die for something so contemptible!

I take heaven to witness that it is only under compulsion that I have yielded to a provocation which I had tried to avert by all means.

I repent having told a baleful truth to men who were so little able to listen to it coolly. Yet I have told the truth. I take with me to the grave a conscience free from lie, free from patriots' blood.

Goodbye! I had in me a great deal of life for the public good.

Forgiveness for those who killed me; they are of good faith.

E. Galois.

Any comment could but detract from the pathos of this document. I will only remark that the last line, in which Galois absolves his adversaries, destroys his brother's theory. It is simpler to admit that his impetuosity, aggravated by female intrigue, had placed him in an impossible position from which there was no honourable issue, according to the standards of the time, but a duel. Evariste was too much of a gentleman to try to evade the issue, however trifling its causes might be; he was anxious to pay the full price of his folly. That he well realized the tragedy of his life is quite clear from the laconic postscriptum of his second letter: *Nitens lux, horrenda procella, tenebris aeternis involuta.* The last letter addressed to his friend, Auguste Chevalier, was a sort of scientific testament. Its seven pages, hastily written, dated at both ends, contain a summary of the discoveries which he had been unable to develop. This statement is so concise and so full that its significance could be understood only gradually as the theories outlined by him were unfolded by others. It proves the depth of his insight, for it anticipates discoveries of a much later date. At the end of the letter, after requesting his friend to publish it and to ask Jacobi or Gauss to pronounce upon it, he added: "After that, I hope some people will find it profitable to unravel this mess. *Je t'embrasse avec*

effusion." The first sentence is rather scornful but not untrue and the greatest mathematicians of the century have found it very profitable indeed to clear up Galois' ideas.

The duel took place on the 30th in the early morning, and he was grievously wounded by a shot in the abdomen. He was found by a peasant who transported him at 9:30 to the Hôpital Cochin. His younger brother—the only member of the family to be notified—came and stayed with him, and as he was crying, Evariste tried to console him, saying: "Do not cry. I need all my courage to die at twenty." While still fully conscious, he refused the assistance of a priest. In the evening peritonitis declared itself and he breathed his last at ten o'clock on the following morning.

His funeral, which strangely recalled that of his father, was attended by two to three thousand republicans, including deputations from various schools, and by a large number of police, for trouble was expected. But everything went off very calmly. Of course it was the patriot and the lover of freedom whom all these people meant to honour; little did they know that a day would come when this young political hero would be hailed as one of the greatest mathematicians of all time.

A life as short yet as full as the life of Galois is interesting not simply in itself but even more perhaps because of the light it throws upon the nature of genius. When a great work is the natural culmination of a long existence devoted to one persistent endeavour, it is sometimes difficult to say whether it is the fruit of genius or the fruit of patience. When genius evolves slowly it may be hard to distinguish from talent,—but when it explodes suddenly, at the beginning and not at the end of life, or when we are at a loss to explain its intellectual genesis, we can but feel that we are in the sacred presence of something vastly superior to talent. When one is confronted with facts which can not be explained in the ordinary way, is it not more scientific to admit our ignorance than to hide it behind faked explanations? Of course it is not necessary to introduce any mystical idea, but it is one's duty to acknowledge the mystery. When a work is really the fruit of genius, we cannot conceive that a man of talent might have done it "just as well" by taking the necessary pains. Pains alone will never do; neither is it simply a matter of jumping a little further, for it involves a synthetic process of a higher kind. I do not say that talent and genius are essentially different, but that they are of different orders of magnitude.

Galois' fateful existence helps one to understand Lowell's saying: "Talent is that which is in a man's power, genius is that in whose power man is." If Galois had been simply a mathematician of considerable ability, his life would have been far less tragic, for he could have used

his mathematical talent for his own advancement and happiness; instead of which, the furor of mathematics—as one of his teachers said—possessed him and he had no alternative but absolute surrender to his destiny.

Lowell's aphorism is misleading, however, for it suggests that talent can be acquired, while genius cannot. But biological knowledge points to the conclusion that neither is really acquired, though both can be developed and to a certain extent corrected by education. Men of talent as well as men of genius are born, not made. Genius implies a much stronger force, less adaptable to environment, less tractable by education, and also far more exclusive and despotic. Its very intensity explains its frequent precocity. If the necessary opportunities do not arise, ordinary abilities may remain hidden indefinitely; but the stronger the abilities the smaller need the inducement be to awaken them. In the extreme case, the case of genius, the ability is so strong that, if need be, it will force its own outlet.

Thus it is that many of the greatest accomplishments of science, art and letters were conceived by very young men. In the field of mathematics, this precocity is particularly obvious. To speak only of the two men considered in this essay, Abel had barely reached the age of twenty-two and Galois was not yet twenty, perhaps not yet nineteen, when they made two of the most profound discoveries which have ever been made. In many other sciences and arts, technical apprenticeship may be too long to make such early discovery possible. In most cases, however, the judgment of Alfred de Vigny holds good. "What is a great life? It is a thought of youth wrought out in ripening years." The fundamental conception dawns at an early age—that is, it appears at the surface of one's consciousness as early as this is materially possible—but it is often so great that a long life of toil and abnegation is but too short to work it out. Of course at the beginning it may be very vague, so vague indeed that its host can hardly distinguish it himself from a passing fancy, and later may be unable to explain how it gradually took control of his activities and dominated his whole being. The cases of Abel and Galois are not essentially different from those contemplated by Alfred de Vigny, but the golden thoughts of their youth were wrought out in the ripening years of other people.

It is the precocity of genius which makes it so dramatic. When it takes an explosive form, as in the case of Galois, the frail carcass of a boy may be unable to resist the internal strain and it may be positively wrecked. On the other hand when genius develops more slowly, its host has time to mature, to adapt himself to his environment, to gather strength and experience. He learns to reconcile himself to the conditions which surround him, widely different as they are, from

those of his dreams. He learns by and by that the great majority of men are rather unintelligent, uneducated, uninspired, and that one must not take it too much to heart when they behave in defiance of justice or even of common sense. He also learns to dissipate his vexation with a smile or a joke and to protect himself under a heavy cloak of kindness and humour. Poor Evariste had not time to learn all this. While his genius grew in him out of all proportion to his bodily strength, his experience and his wisdom, he felt more and more ill at ease. His increasing restlessness makes one think of that exhibited by people who are a prey to a larvate form of a pernicious disease. There is an internal disharmony in both cases, though it is physiological in the latter, and psychological in the former. Hence the suffering, the distress and finally the acute disease or the revolt!

A more congenial environment might have saved Galois. Oh! would that he had been granted that minimum of understanding and sympathy which the most concentrated mind needs as much as a plant needs the sun! . . But it was not to be; and not only had he no one to share his own burden, but he had also to bear the anxieties of a stormy time. I quite realize that this self-centered boy was not attractive—many would say not lovable. Yet I love him; I love him for all those who failed to love him; I love him because of his adversity.

His tragic life teaches us at least one great lesson: one can never be too kind to the young; one can never be too tolerant of their faults, even of their intolerance. The pride and intolerance of youth, however immoderate, are excusable because of youth's ignorance, and also because one may hope that it is only a temporary disorder. Of course there will always be men despicable enough to resort to snubbing, as it were, to protect their own position and to hide their mediocrity, but I am not thinking of them. I am simply thinking of the many men who were unkind to Galois without meaning to be so. To be sure, one could hardly expect them to divine the presence of genius in an awkward boy. But even if they did not believe in him, could they not have shown more forbearance? Even if he had been a conceited dunce, instead of a genius, could kindness have harmed him? . . . It is painful to think that a few rays of generosity from the heart of his elders might have saved this boy or at least might have sweetened his life.

But does it really matter? A few years more or less, a little more or less suffering. . . . Life is such a short drive altogether. Galois has accomplished his task and very few men will ever accomplish more. He has conquered the purest kind of immortality. As he wrote to his friends: "I take with me to the grave a conscience free from lie, free from patriot's blood". How many of the conventional heroes of history, how many of the kings, captains and statesmen could say the same?

MARS AS A LIVING PLANET

By G. H. HAMILTON
LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA

IN contradistinction to the Moon as a *dead* world, I can speak of Mars and the Earth as *living* planets.

It is the purpose of this paper to present observational evidence to show that Mars has an atmosphere and is imbued with a considerable degree of warmth—that the changes observed upon its surface would necessitate such an atmosphere, in fact that the planet approaches the conditions that we know upon the Earth, even if it does not quite attain them.

To approximate the unchangeableness and sterility seen on the Moon—because of its lack of atmosphere and the intense cold due to its long night—it would be necessary here on Earth to resort to a vacuum or other preservatives. A similar condition on Mars is inconceivable from what we know of its surface features and the changes which have occurred in them from the earliest reliable observations. Disintegration and growth depend, not only on the action produced by atmosphere but also on the presence of organisms. It is true that inorganic material suffers change from mechanical and chemical action, but this again admits water and atmosphere into the consideration of its cause.

CLOUD OVER SOUTHERN PORTION OF SYRTIS MAJOR

1903 June 1 P. L.

1920 May 26 G. H. H.

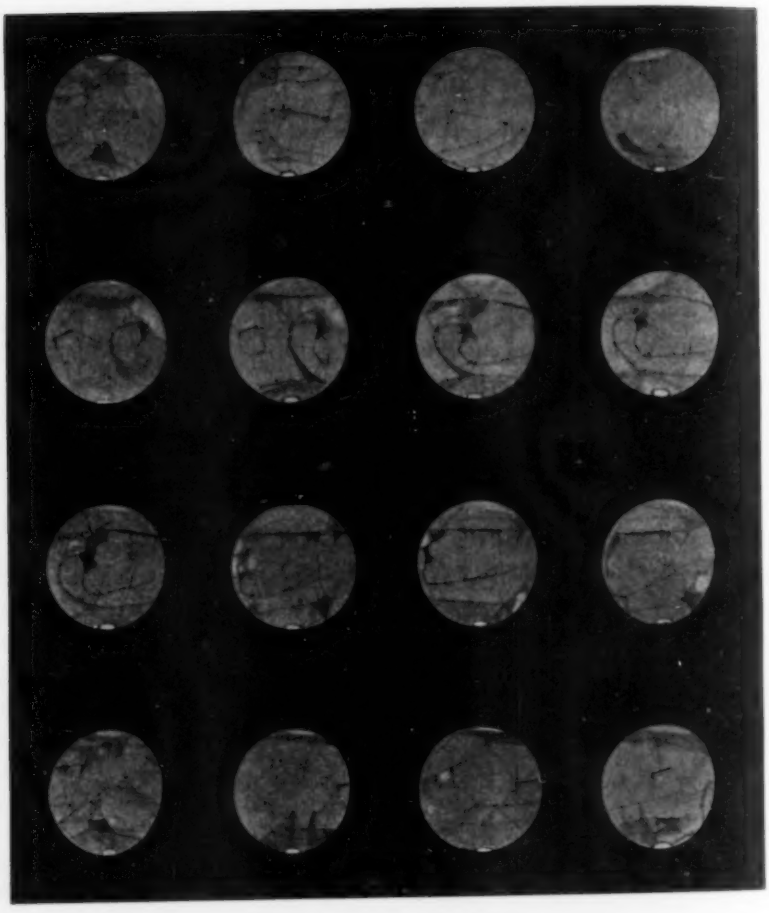
The germination and gemination of the canals from the time of Schiaparelli show an unaccountable seasonal change, if we are to believe in a cold as intense as that which some people have suggested exists, or an atmosphere so thin that it would be lacking in those gases commonly supposed necessary for the support of organic material. One would hardly suppose that an atmosphere sufficiently dense to produce mechanical changes to the extent that they have been observed in inorganic matter, would have little or no effect in the production of organisms.

The dependence of the canals on the seasons of Mars for their visibility established by Lowell, and the variations in the dark areas are confirmatory evidence of an atmosphere; for these changes would be inexplicable on any object, most certainly a planet, placed in a refrigerator or vacuum bell.

There were, at this opposition, two regions on the planet where a considerable haze existed; this was very evident near either limb, but when these regions were on or near the center of the disk the haze was only noticeable by its diffusing and dimming effect on the surface markings. It appeared to cover the Syrtis Major and its surroundings, and also a region opposite—about the Lacus Lunae south of the Mare Acidalium. Detail outside of these regions was usually clear cut.

When on the limb or terminator, i. e., near sunrise or sunset, the haze above these regions seemed to condense and became itself visible in the form of a dull blue-white covering very easily seen on account of the contrast of this color to that of the surrounding desert or dark areas over which it appeared to hang. These condensations in the haze remained of a nearly constant area close up to the terminator, and remained close to the terminator during the time that they lasted. In consequence those areas of the planet coming onto the disk from the terminator or leaving the disk, appeared from behind this covering or disappeared under it in a remarkable manner. The change in formation of these blue-white areas was of a character that one would expect if it had been atmospheric and cloud-like in nature. It was decidedly an evening and morning effect. The shift of the surface of the planet with respect to these apparent clouds was incompatible with the assumption that they belonged to the surface, but pointed expressly to the fact that they were above the surface and atmospheric.

This article is illustrated by two plates. The first shows two drawings, one made in 1903 by Dr. Lowell, the other in 1920, by myself. Dr. Lowell's drawing of June 1, 1903, depicts a season, for that region on Mars, corresponding on our Earth to August 6. It is interesting to note that my drawing of May 26, 1920, shown with his, corresponds in season to about August 13. It will be noticed that though a period of seventeen years has elapsed, the cloud formation is very similar over



MARS 1920

Mar. 8	Mar. 5	May 11	May 11
$\lambda = 34$	$\lambda = 63$	$\lambda = 127$	$\lambda = 91$
Apr. 28	May 26	May 24	May 26
$\lambda = 250$	$\lambda = 262$	$\lambda = 305$	$\lambda = 308$
May 22	Apr. 13	May 24	June 21
$\lambda = 312$	$\lambda = 344$	$\lambda = 342$	$\lambda = 1$
June 21	June 5	May 7	June 4
$\lambda = 51$	$\lambda = 168$	$\lambda = 166$	$\lambda = 211$

George Hall Hamilton.

$\lambda =$ Longitude of Central Meridian at time of drawing.

the Syrtis at approximately the same season. The drawings, of course, have only been used in comparison for this particular feature.

The second plate, made up of sixteen selected drawings, not only shows the curious cloud formation over the Syrtis Major and the Mare Acidalium, but also gives one a complete view of the Martian surface except that portion near the southern pole which was continuously turned away from us at this opposition.

It will be noticed from these drawings that both the Syrtis and the Mare Acidalium are nearly completely free from cloud when on the center of the disk, but that they are covered by cloud to a great extent when near the limb or terminator.

The drawings, which are typical of all those made at this opposition, show unmistakeable evidence of a considerable atmosphere. This can not be wondered at when one realizes the amount of water vapor transported from one pole to the other each Martian half-year: it is an atmosphere quite capable of being, in fact, a mechanical transferer of this material from pole to pole.

That Mars is a living planet seems certain from these changes that are seen to continually take place on its surface and above the ground. The dark areas and canals are seemingly, at least in part, organic. The polar caps by their disappearance and reappearance each year, imply *both mechanical and physical* change, as do also the daily variations in the cloud formations.

How far organic evolution has progressed it would be hard to tell, but that there is a succession of seasons on Mars as on the Earth, and consequent germination is evident.

THE PROGRESS OF SCIENCE

SCIENTIFIC MEETINGS

We are able to print in the present issue of THE SCIENTIFIC MONTHLY extracts from addresses given at the meeting of the British Association held at Edinburgh from September 7 to 14. The meeting is in progress as this journal goes to press, and practically nothing from England regarding its proceedings has been cabled. The addresses of the president of the association and of the presidents of the sections are usually the best summaries of the progress of science prepared each year, and the English newspapers and journals have been in the habit of paying much more attention to them than is the case in this country with the corresponding addresses of the American Association. This more general attention naturally causes the preparation of addresses of greater interest, which in turn leads to their more widespread publication to the advantage of science and of the national welfare.

The American Association meets this year at Toronto, and the meeting should be of more than usual interest. Dr. L. O. Howard, chief of the Bureau of Entomology of the Department of Agriculture, who gives the address of the retiring president, is master of a subject of great scientific and economic concern, and it is desirable that his address and the addresses of the vice-presidents and the other proceedings of more than technical interest should be given wide publicity. It is to be hoped that the recently organized Science Service may be of use in this direction. Two distinguished English men of science have been invited to Toronto as guests of the association, one in the biological and one in the physical sciences, and Professor Bateson has consented to be present.

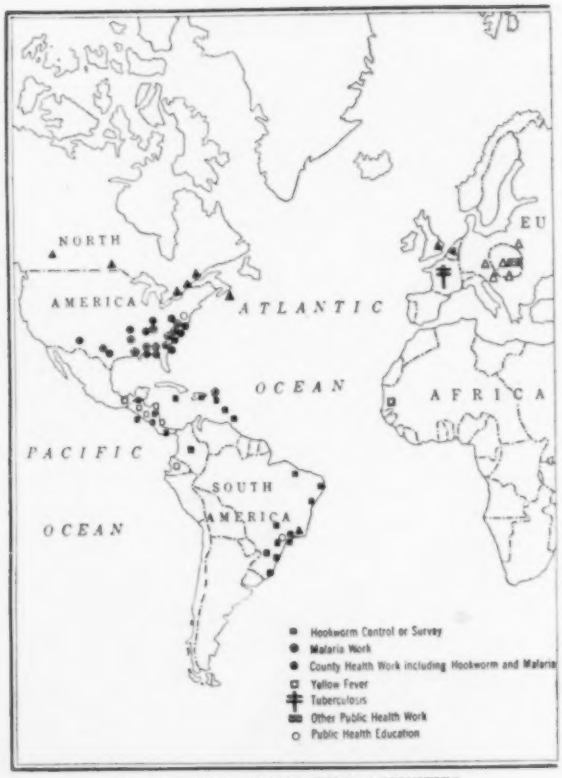
At the same time as the meeting of the British Association in Edinburgh, the chemists have been holding Anglo-American meetings. The British Society of Chemical Industry met with the Canadian Branch in Montreal under the presidency of Sir William Pope, professor of chemistry in the University of Cambridge. After visits to Ottawa and Toronto, the English and Canadian chemists joined in the New York meeting of the American Chemical Society. The number was small, but they were admirably represented by their president, who took part in the international program and made an address at the dinner. The American Chemical Society was also fortunate in its president, Dr. Edgar Fahs Smith, provost emeritus of the University of Pennsylvania, who first held the office twenty-five years ago. In his presidential address, in his address at the dinner and at the meetings on educational chemistry and the history of chemistry, Dr. Smith did much to emphasize the broader aspects of the science.

In the attendance and on the programs, industrial and engineering chemistry were largely represented. Much interest was manifested in the embargo on German chemicals and in the Chemical Warfare Service. There were elaborately arranged excursions to industrial plants in and around New York City and during the week following the meeting a large national exposition of Chemical Industries was held in one of the armories of the city.

Following the meeting of the chemists an International Congress of Eugenics is being held in New York City. While the time has scarcely come when international congresses can be held and while eugenics ap-

Photograph by Underwood and Underwood.

SIR WILLIAM POPE
President of the Society of Chemical Industry



MAP SHOWING WORLD-WIDE ACTIVITIES

pears to be still an amateur science, mainly promoted by amateurs, the meeting promises to be of interest. The program gives prominence to genetics which has become a real science in which America may perhaps claim leadership. At the opening meeting addresses were announced by Dr. Henry Fairfield Osborn, president of the congress and of the American Museum of Natural History; Major Leonard Darwin, president of the Eugenics Education Society, London; and Dr. Charles B. Davenport, director of the Department of Genetics of the Carnegie Institution. Among those from abroad who make addresses before the sections are M. Lucien Cuénot, Nancy, France; Professor Herman Lundborg, Upsala, Sweden, and M. Georges Vacher de Lapouge, Poitiers, France.

THE ACTIVITIES OF THE ROCKEFELLER FOUNDATION

The president of the Rockefeller Foundation, Dr. George E. Vincent, has issued a popular review of the work carried out during the year 1920, which gives a good idea of its magnitude and wide influence in aid of medical education and in the field of public health. A map of the world showing the widespread distribution of the various activities of the foundation is here reproduced. The total endowment now amounts to over 174 million dollars, and during the year approximately seven million dollars have been spent in carrying out the program of the foundation. Of this amount, over two million dollars were contributed for the improvement of the public health in various

OF THE ROCKEFELLER FOUNDATION

parts of the world, especially towards the eradication of hookworm, malaria and yellow fever, and the establishment of adequate institutions for the training of public health officials. Over $300,000 was given to the School of Hygiene and Public Health of the Johns Hopkins University.

In its second great field of endeavor, that of improving the standards of medical education, the foundation has expended nearly four and a half million dollars during the year. The greater part of this sum has been used for the building and equipment of a medical school in China, the Peking Union Medical College, and to aid other schools already established in that country. Substantial sums have been pledged to the University College Hospital in London—a total of about five million dollars, to be equally divided between buildings and endowments for increased education and research facilities. In addition, aid has been given to a number of schools in this country and in Canada.

The foundation has contributed to the support of a number of humanitarian and charitable organizations, including the appropriation of a million dollars to the child-feeding fund of the American Relief Administration, and to various miscellaneous enterprises having for their object the stimulation of research and the improvement of the medical standards of the world.

The report indicates that good progress is being made in the aim of the Rockefeller Foundation to increase the common store of knowledge of the causes of disease, and through demonstrations and the ser-

vices of trained experts to diffuse this information as widely as possible among all peoples.

THE HARVARD SCHOOL OF PUBLIC HEALTH

Plans for the organization of a School of Public Health in Harvard University, with the aid of an initial gift of $1,785,000 by the Rockefeller Foundation, are announced by the university and the officers of the foundation. The announcement says that an excellent general course for the training of public health officers as well as special courses in preventive medicine, in tropical medicine and industrial hygiene have already been developed at Harvard. The work has been hampered, however, by lack of adequate funds and by uneven growth.

The new school will provide opportunities for research, will unify existing courses and will offer new or extended teaching facilities in public health administration, vital statistics, immunology, bacteriology, medical zoology, physiological hygiene and communicable diseases.

For the housing of the school the university hopes to secure an existing building of very suitable character immediately adjacent to the Medical School. Funds for the purchase and equipment of the building will be drawn from the gift of the Rockefeller Foundation. The cost of maintenance and development of the school will be met from endowment funds in part set aside by the university and in part contributed by the Foundation. The Foundation's immediate appropriations to the project will aggregate $1,785,000. The arrangement also provides for further gifts, if the growth of the school seems to demand it, to any amount which shall not exceed $500,000.

Though the School of Public Health at Harvard will have its headquarters in a well-equipped building of its own and have its own separate faculty and administration, it will be developed in close relation with other divisions of the university, especially the Medical School. The administration buildings of the two schools will, it is hoped, stand side by side on the same grounds; certain heads of departments will be members of both faculties; and a number of laboratories and lecture rooms will be used in common.

The school will be able to cooperate with a large number of laboratories, hospitals and public health agencies in Boston and thus afford its students unusual opportunities for first-hand investigation and practical field experience. In addition, the school, through cooperative relations with a number of manufacturing and commercial corporations, will be able to offer the students practical experience in industrial hygiene.

SCIENTIFIC ITEMS

We record with regret the death of Joel Asaph Allen, curator of the Department of Birds and Mammals at the American Museum of Natural History; of George Trumbull Ladd, for forty years professor of moral philosophy and metaphysics at Yale University; and of Peter Cooper Hewitt, the electrical and mechanical engineer of New York City.

On July 21, a memorial was unveiled in the public gardens at Dartmouth to the memory of Thomas Newcomen, the pioneer of the steam engine. Newcomen was born in Dartmouth in 1663; he followed the trade of blacksmith there, and was also a Baptist preacher.

The John Burroughs Memorial Association has been inaugurated at a meeting of a number of his friends at the American Museum of Natural History, the immediate purpose of the association being to protect Mr. Burroughs' home and camps and to preserve them, with their wild life, for future generations.